STUDIES ON THE LEPTOCEPHALI OF DEEP SCATTERING LAYER (DSL) OF THE SOUTH WEST COAST OF INDIA

Thesis submitted to the

KARNATAK UNIVERSITY

in

partial fulfillment for the degree of

DOCTOR OF PHILOSOPHY

in

MARINE BIOLOGY

By

BALU.S

SCHOOL OF OCEAN SCIENCES

KARNATAK UNIVERSITY POST GRADUATE

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INDIA

2004

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CERTIFICATE

Certified that the thesis entitled **"Studies on the Leptocephali of Deep Scattering Layer (DSL) of the south west coast of India"** by **Mr. BALU.S** for the degree of **Doctor of Philosophy** in Marine Biology, Karnatak University, is a record of bonafide research work carried out by him under my supervision and guidance and that the thesis or a part there of has not formed the basis of any degree, diploma or any other similar title.

(KUSUMA NEELAKANTAN)
Supervising Teacher

DECLARATION

I here by declare that this thesis entitled **"Studies on the Leptocephali of Deep Scattering Layer (DSL) of the south west coast of India"** is an authentic record of work done by me and no part has been presented for award of any degree, diploma or other similar title.

(BALU.S)

Dedicated

to

My Beloved Parents

ACKNOWLEDGEMENT

I express my deep sense of gratitude to my Supervising Teacher Dr. (Mrs.) **Kusuma Neelakantan**, Chairperson, School of Ocean Sciences, Karnatak University Post Graduate and Research Center, Karwar, for her guidance, invaluable suggestions and constant encouragement for the successful completion of the work.

I am extremely grateful to the Late Professor, Dr. B. Neelakantan, former Chairman, School of Ocean Sciences, Karnatak University Post Graduate and Research Center Karwar, for his timely and unconditional help and encouragement.

I express my sincere gratitude to the present Director of C.M.F.R.I, Cochin, Dr. Mohan Joseph Modayil and former Directors of C.M.F.R.I, Dr. M. Devaraj, Dr. V.N.Pillai for providing the necessary facilities at the institute for my research work.

I deeply acknowledge the constant encouragement and invaluable suggestions and advices given by Dr. N.G. Menon, Principal Scientist and Principal Investigator of the DOD-DSL Project, C.M.F.R.I., Cochin, through out the period of study.

I place in record my sincere thanks to Dr. K. H. Mohamed for his keen interest in the subject and for critically going through the manuscript with valuable suggestions.

My sincere thanks are also due to Dr. V.G. Bhat, Reader and Mr. J.L.Rathod, Lecturer, both of the School of Ocean Sciences, Karnatak University Post Graduate and Research Center, Karwar, for their help and support.

I express my gratitude to Dr. R.S.Biradar, Principal Scientist and Controller of Examinations, C.I.F.E., Mumbai, for his timely action in processing and sending the migration certificate. I also thank Mrs. Arati Revankar for her generous help rendered for the processing of migration certificate at C.I.F.E, Mumbai and unconditional support.

I am extremely grateful to Dr. K.K.Joshi, Senior Scientist and Mr. K. Balachandran, Technical Officer, both of Demersal Fisheries Division of C.M.F.R.I., Cochin, for their unconditional help and support and for critically scrutinizing the manuscript with valuable suggestions.

It is my pleasure to acknowledge the kind of support and encouragement given by Dr. (Mrs.) L. PrabhaDevi, Lecturer, School of Advance Life Sciences of M.G. University, Pathanamthitta, Dr. A. A. Jayaprakash, Principal Scientist, Pelagic Fisheries Division of C.M.F.R.I., Cochin; Dr.K.K.Appukuttan, Principal Scientist and Head, Dr. (Mrs) V.Kripa and Dr. P.Laxmilatha, Senior Scientists, Dr. (Mrs.) Shoji Joseph, Scientist, Mr. Mathew Joseph and Mrs. Jenni Sharma, Technical Officers, all of the Molluscan Fisheries Division of C.M.F.R.I., Cochin; Dr. George J.P, Principal Scientist, Fisheries Environment Management Division and Mrs. Rekha J. Nair, Scientist, Demersal Fisheries Division, both of C.M.F.R.I., Cochin, Mr. V. Edwin Joseph, Technical Officer (Librarian), C.M.F.R.I., Cochin and Dr. A. Gopalakrishnan, Senior Scientist of the N.B.F.G.R., Cochin.

I express my sincere thanks to Ms. Sherri Charter, Research Fishery Biologist, NMFS, South west Fisheries Science Center, La Jolla, California, U.S.A, for her subject expertise, valuable suggestions and for providing important references with out hesitation and delay, as and when requested. I also thank Ms. Rosalie Shaffer, Technical Information Specialist of the NMFS, Panama City Laboratory Library, Florida, U.S.A. for the quick response to my requests for references.

It is with great pleasure I would thank Dr. Satish Sahayak, Project Scientist, Regional Center of N.I.O, Cochin, for his technical excellence in photography and unconditional help. I also thank Mr. K.K. Shankaran, Artist, C.M.F.R.I., Cochin, for his artistical capabilities in making the graphs and maps.

I express my gratitude to all my friends and colleagues for their unfailing help and support during various stages of my study with special mention to Dr. Manoj Nair. R; Dr. F. G. Benno Ferreira and Dr. G. Prasad, both Lecturers of St. Albert's College, Cochin; Dr. P. K. Karuppasamy, Project Scientist, Regional Center of N.I.O, Cochin; Dr. Vimala P.T, *Mrs. Simmy George, Dr. Soniraj N, Dr. Anilkumar P.K, Dr. Girish R, Dr. and Mrs. Rammohan, Dr. Seema Khot, Mr. Rajesh B, Mr. Baiju S, Mr. Manoj B. Dethan, Mr. Unnikrishnan. V, Dr. Abraham K.J, and Mrs. Anikumari, Miss. Anjana Mohan, Miss. Jugnu R, Miss. Sreejaya R, Mr. Ramalinga, Mr. M. Vinod, Mr. P.S .Alloycious and Mr. M.N .Satyan of the Molluscan Fisheries Division, C.M.F.R.I., Cochin.*

I wish to express my thanks to the Department of Ocean Development, Govt. of India, New Delhi, for providing the leptocephali collection of FORV Sagar Sampada from the west coast at my disposal and for granting me Senior Research Fellowship with out which the present study was not possible. With much gratitude I extend my sincere thanks to Dr. V. Ravindranathan, Advisor, Dr. V.N. Sanjeevan, Principal Scientific Officer and other staff of C.M.L.R.E of DOD, Cochin, for their kind cooperation and timely help. My thanks are also due to the Officers and crew of S.C.I; Fishing Masters and Fishing Hands of DOD and the Service Engineers of NORINCO on board FORV Sagar Sampada for their help and cooperation rendered during the cruises.

Lastly, it is my pleasure to express my gratitude to my Parents, Brother and family and to my Wife for their love, support and constant encouragement through out the period of study.

Contents

Introduction

Introduction

The waters of the World Ocean, from the surface to the deepest reaches of the bottom trenches, have a total volume of about 1.4 million cubic kilometeres, more than 99% of Earth's biosphere. One of the most important discoveries of early oceanographic expeditions was the great variety of deep ocean life, well adapted to pressure and cold. Since then, sampling with trawl nets and more recently with acoustics and submersibles has increased our understanding of the under water fauna, but it remains one of the least explored environments on earth. This vast habitat is home to far fewer species than any terrestrial or near shore marine environment.

The mid-water can be divided into two major regions ie. mesopelagic and bathy pelagic - based on depth, with very different physical and biological attributes. The mesopelagic zone (200-1000 m), is a twilight region where sunlight is too weak to support photosynthesis, but penetrates sufficiently to affect the behaviour of animals, on a diurnal schedule, that is, the animals living there can see and react to the changing light levels and the bathypelagic zone (>1000 m), accounting for 88 % of the total Ocean area and covering the entire deep ocean floor where there is no light, the temperature is cold and constant and food is scarce. The proximity of upper water primary production makes it possible for many herbivores to live in the mesopelagic zone and perhaps half the species are vertical migrators who spend the day at depth but come to the rich surface waters at night to feed on phytoplankton or other animals. The general pattern of daily or diurnal vertical migration has been deduced from numerous sources of information. Net collections of animals from several depths at different times throughout the day have shown that more animals are near the surface at night. Under water sound pulses from ship mounted echo sounders have also been used extensively to study the behaviour of vertically migrating animals. These pulses are partially reflected by the concentration or layers of mid-water animals and appear as a "false bottom" on the echogram. These diurnally, vertically moving bio acoustic layers or "false bottoms" are called Deep Scattering Layers (DSL) or Sound Scattering Layers (SSL).

The existence of "deep scattering layer" in the Ocean was discovered by Eyring, Christensen and Raitt during 1942 while working for the University of California, Division of War Research. The wide spread occurrence of deep scattering layers in world oceans and their rich bio-composition aroused scientific interest ever since their discovery (Duvall and Christensen, 1946; Eyring *et al.*,1948 and Raitt, 1948).

The DSL is an important ecosystem of world oceans and supports a wide assemblage of zooplankton, micro and macro nekton. The bio-composition of the deep scattering layers of the world ocean has been well described by Marshall (1951), Tucker (1951), Barham (1957), Pearcy and Laurs (1966), Taylor (1968), Kinzer (1969), and Silas (1972) showed the predominance of macroplankton and micro nekton in the DSL. The above studies also indicated the occurrence of a wide assemblage of young or adults of epipelagic, mesopelagic and to a lesser extent bathypelagic fishes. The availability, abundance and vertical migration of these fishes are influenced or controlled by the occurrence and quantity of favourite food components of DSL.

In spite of a rather rich literature available on the DSL of many parts of the world oceans (Anon, 1946; Dietz, 1948; Raitt, 1948; Boden, 1950, 1962; Moore, 1950; Hersey *et al.*, 1952; Bernard, 1955; Uda, 1956; Backus and Barnes, 1957; Clarke and Backus; 1964; Barham, 1966; Barry, 1966a,b; Kinzer, 1969), the Indian Ocean, particularly the Indian Seas remained the least investigated for the DSL. The information available for the Indian Ocean is those of Daniel *et al.* (1969), Silas (1972), Menon (1990), Menon and Prabha Devi (1990), James and Prabha Devi (1990), Mini Raman and James (1990), Mathew and Natarajan (1990), Balasubramaian and Suseelan (1990) and Suseelan and Manmadan Nair (1990). A preliminary study of the zoological constituents of the sonic scattering layer was made by Daniel *et al.* (1969) based on observations made at seven stations in the Bay of Bengal. Silas (1972) made some valuable studies on the DSL in the Lakshadweep

Sea and Menon (1990) investigated on the fish biomass in the Deep Scattering Layers of the EEZ of India. In their investigations on the various aspects of Deep Scattering Layer of Indian EEZ, Menon and Prabha Devi (1990) studied the total biomass, James and Prabha Devi (1990) on the leptocephali, Mini Raman and James (1990) on the Myctophids, Mathew and Natarajan (1990) on the Euphausiid component, Suseelan and Manmadan Nair (1990) on Pelagic Shrimps and Balasubramanian and Suseelan (1990) on the swarming crabs.

Studies carried out on the biomass of the Deep Scattering Layer of the Indian EEZ during the cruises of FORV Sagar Sampada (1985-1987) revealed that 94% of the total biomass was composed of plankton and 6% by micro and macro nekton. The micro nekton was represented by Euphausiids, Decapods, Siphonophores, Copepods, Pteropods, Heteropods, Amphipods, Ostracods, Chaetognaths, Larval Crustaceans and the macronekton by a concentration of fishes of families like Myctophidae, Gonostomatidae, Photichthyidae, Bregmacerotidae and Leptocephali and juveniles of several other families of fishes. Among the macro-nekton, Leptocephali formed one of the most important groups of the DSL biomass. It constituted about 7.5% of the total fish biomass in the DSL of the EEZ of India (Menon, 1990).

Leptocephali, the larval forms of eels are distinctive among larval fishes (Smith, 1989 a; Hulet and Robins, 1989). A small, thin, laterally compressed head gives the leptocephalus its name (leptocephalus = “slender head”). Their body is laterally compressed, largely shaped by a gelatinous material surrounded by a thin layer of myotomal muscle (‘V’ or ’W’ shaped), have a simple gut and are nearly transparent. They possess well-developed eyes, olfactory organs and have a series of strong, fang like, forwardly directed teeth. The Leptocephalus stage lasts for months to years, and grow to a large size for larval fishes, typically 50-100 mm (Bohlke, 1989 b), but much more in some species (Smith, 1989 b-d), before metamorphosing into elvers. A pelagic, long-lived Leptocephalus is common to the families of eels, whether the juveniles inhabit the open ocean, shelf waters or estuarine and fresh waters. They inhabit the upper few hundred meters of the water column throughout the world oceans, primarily in tropical and sub tropical areas. Although leptocephalus is a larval type shared by the Elopiform, Saccopharyngiform and Notacanthiform fishes, the largest groups of fishes with this type of larva are the eels of the order Angulliformes. Leptocephali in the DSL were mainly represented by the families of the order Angulliformes viz.,Congridae, Muraenidae, Muraenesocidae, Synaphobranchidae, Nettastomatidae, Nemichthyidae, Ophichthyidae etc. Leptocephali of the order Elopiformes were also represented in few instances.

The study on the development of the eel has been made classic by the wonderful researches of Schmidt (1922a, 1923a, 1924d, 1925), that the European eel *Anguilla anguilla* and the American eel *Anguilla rostrata* grow in European and American rivers and go down to the Atlantic and returned as elvers after a prolonged larval period as leptocephali, has been well established. Very little, however is known regarding the breeding of the Indian freshwater eels such as *Anguilla bengalensis* and *Anguilla bicolor* except for scattered references of their occurrence in some Indian rivers. Similarly very little literature is available about the breeding habits of the Indian marine eels, such as, *Muraenesox cinereus, Muraenesox talabon, Muraenesox talabonoides* (Family Muraenesocidae) *Uroconger lepturus* (Family Congridae), eels of the families Ophichthidae, Muraenidae etc.

As the food from the land is so limited that it may not be able to satisfy even the basic requirements of the ever increasing human population, an alternative to over come this problem is to tap the vast unexploited resources of the ocean which could nourish the population many times more than its present level. Eel is one such resource and is considered as a luxury food and consumed in delicacy by Greeks, Romans, Japanese and people of several Asian and European countries. Even though it is considered as a food fish in India their exploitation is limited. But their export demands offers scope for culture and live transport to foreign markets, besides increasing their exploitation from all along the distributional range.

Very few workers have focussed their attention to study the systematics of the leptocephalus larvae. Much work has been published on the anguillid leptocephali of the temperate and sub-tropical regions. Several cruises were also conducted to locate the breeding grounds of the American and European eels in relation to water masses and other oceanographic features (Kleckner and Mc Cleave, 1985; Mc Cleave and Kleckner, 1987; Castonguay and Mc Cleave, 1987). Karmovskaya (1986) worked out in detail the identification of leptocephali of Angulliformes based on the collection from the world oceans. But no such studies have been carried out along the seas of Indian subcontinent so far, except for some scattered reports. Most of the work from India was concentrated on the study of metamorphosis of leptocephali and also identifying and relating them to their respective adults. (Aiyar *et al.* (1944), Bapat (1955), Gopinath (1946,1950), James and Prabhadevi (1990), Jones and Pantulu (1952,1955), Nair (1946, 1947,1948), Nair and Bhimachar (1950), Nair and Mohamed (1960 a,b,c,d,e) and Pantulu and Jones (1954)). Some studies were also carried out on the eel eggs and their development (Aiyar *et al.*, 1944; Nair and Bhimachar, 1950; Bapat, 1955; Nair and Dharmamba, 1960; Ganapati and Raju, 1960, 1963; Bensam, 1966; Rani Mary George, 1987).

In view of the scanty records of Indian leptocephali, a thorough and systematic study of these larvae together with a knowledge of their distribution is an important and necessary prelude to the study of the biology of the Indian eels, of which we know so little while great advances have been made in the study of their European counterpart. In the present study an attempt is made to evaluate the distribution and abundance of Anguilliform leptocephali in space and time and also to study their metamorphosis in order to estimate their resource potential. Samples for the study were collected during the cruises of FORV Sagar Sampada from 1998-2001 as part of the Department of Ocean Development (DOD), Govt. of India, funded project "Studies on Deep Scattering Layer". The commissioning of the research vessel FORV Sagar Sampada for resource surveys in the Indian EEZ and contiguous water was a milestone in the history of fisheries research, which gave an excellent opportunity to make a comprehensive study on this subject.

Material and methods

Material and methods

The material for the present study was collected from the cruises of FORV *Sagar Sampada* (Fig.1) along the west coast of India (64° - 77°E longitude; 6° - 21°N latitude) during May 1998 to June 2001. Details of the cruise tracks, station positions, depth, time, duration of gear operation and other operational details were collected from the cruise reports of FORV *Sagar Sampada* covering the area of investigation.

Samplings on the Deep Scattering Layer (DSL) were carried out using two types of gears – Isaacs - Kidd Midwater Trawl (IKMT) and Midwater Trawl. IKMT is a specifically designed gear to collect meso and bathy pelagic specimens larger and more active than the plankton taken by standard plankton nets. The Isaacs - Kidd Midwater Trawl (IKMT) (Fig.2) was originally conceived and developed by John D. Isaacs and Lewis W. Kidd (1951) of the University of California's Scripp's Institution of Oceanography. It consists essentially of a net made of nylon attached to a 'V'- shaped rigid, aluminum depressor. The IKMT on board FORV *Sagar Sampada* is made of nylon webbing with four sections of different mesh sizes of 25mm, 16mm, 11mm, and 5mm and length of 500mm, 500mm, 8250mm, and 1750mm, respectively, totaling 11m. The width tapered from 2500m to 750mm, from the mouth opening to the cod end. The 'V'- shaped aluminium depressor weighing 25kg and 2.5m length is attached to the mouth opening in order to maintain the proper opening of the net at a predetermined depth of operation. A five litre capacity bucket is attached to the cod end where the sample gets collected. IKMT was operated on the basis of DSL recordings in the echo sounders (38K Hz and 120 K Hz). It was operated to a maximum depth of 750m during the present study. Samples for the present study was mainly from IKMT.

IKMT was mainly operated on the principal layer and also on all layers, wherever multi layered DSL were sighted. The towing speed of ship was maintained between 3 – 4 knots for a period of 30 minutes. The sample collected was first washed in seawater and then the total volume taken using a standard measuring cylinder. It was then filtered and preserved in 5% formalin with proper labeling. In

Fig. 1. FORV Sagar Sampada

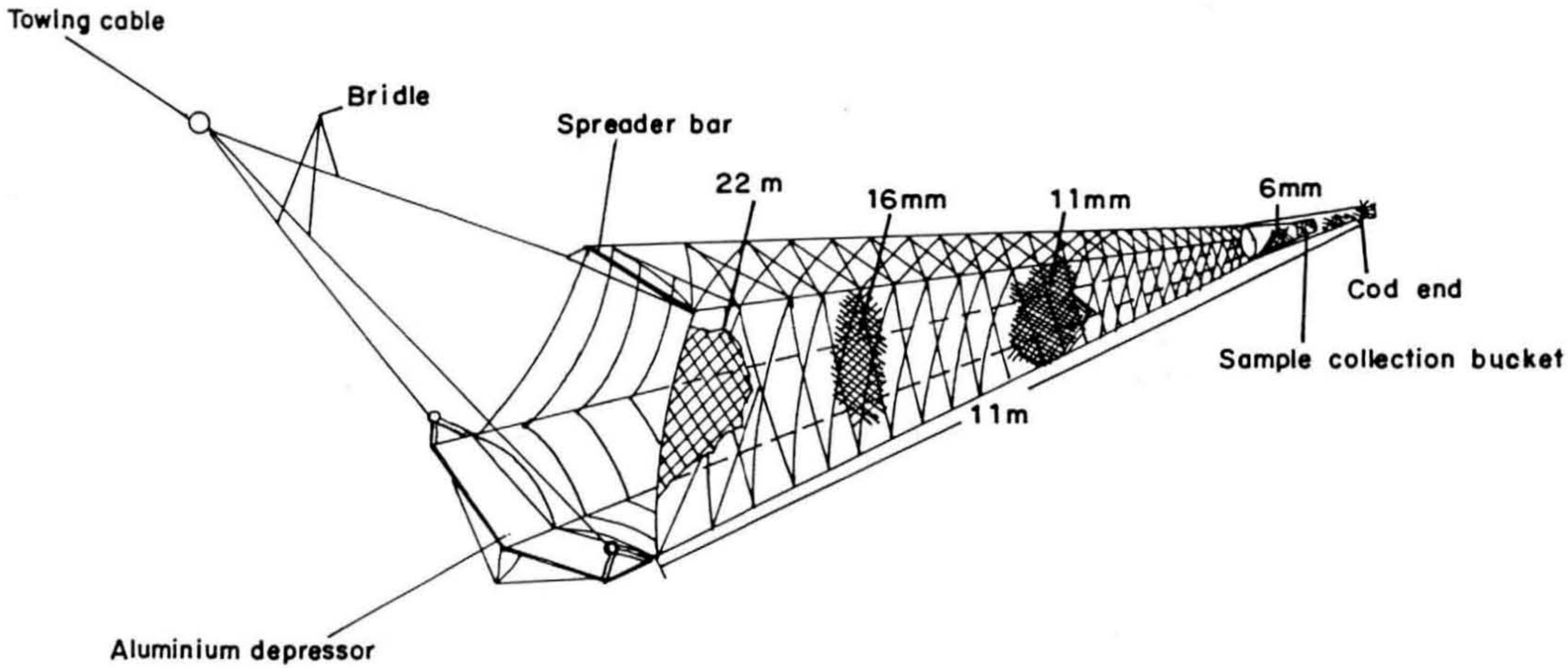


Fig: 2. Rigging of Isaacs-Kidd Midwater Trawl the shore laboratory the samples were analyzed for systematic studies, distribution, biomass estimation and for studying the metamorphosing stages.

The literature on the Indian leptocephali were scanty, except for some scattered works by Aiyar et al. (1944), Panikkar and Nair (1945), Gopinath (1946, 1950), Nair (1946, 1947, 1948, 1960), Nair and Bhimachar (1950), Johns and Pantulu (1952, 1955), Pantulu and Jones (1954) Nair and Dharmamba (1960), Nair and Mohamed (1960 a - e) Ganapati and Raju (1961), etc., the identification of leptocephali to family level and in some cases down to genus and species level, were carried out mainly with the key formulated by Smith (1979). For the systematic studies a total of 23 characters (morpho metric and merisrtic) were taken onto consideration, as given below:

Morphometric Characters	**Meristic Characters**
Total length	Total Myomeres
Standard length	Anal Opening
Maximum Height (excluding fins)	Pre anal Myomeres
Length of Head	Post anal Myomeres
Length of Upper Jaw	Origin of Dorsal fin
Length of Lower Jaw	Dorsal fin Rays
Length of Snout	Anal fin Rays
Diameter of Eye	Caudal fin Rays
Position of Nasal Pit	Teeth in Upper Jaw
Position of First Nostril	Teeth in Lower Jaw
Size of First Nostril	
Position of Second Nostril	
Size of Second Nostril	

Due to its mucilaginous nature, weights of the leptocephali were not taken into consideration.

Length measurements and maximum body height were taken using a standard measuring board. In case of specimens with a damaged caudal fin, only standard length was taken. Length of head was taken using a divider. Other measurements like length of upper and lower jaws, snout; diameter of eye; position of nasal pit, first and second nostrils and size of first and second nostrils were taken using an ocular micrometer (Erma Inc., Japan) calibrated to the nearest millimeter in a compound microscope (Getner). The meristic measurements include total, pre and post anal myomeres; dorsal, anal and caudal fin rays; teeth on upper and lower jaws etc. Counting of the myomeres and teeth were done using a stereo zoom microscope (Ceti, Belgium). Positions of anus and dorsal fin origin were ascertained with the corresponding myomeres, so it was also included in the meristic counts. The morphometric measurements taken are given in Fig.3.

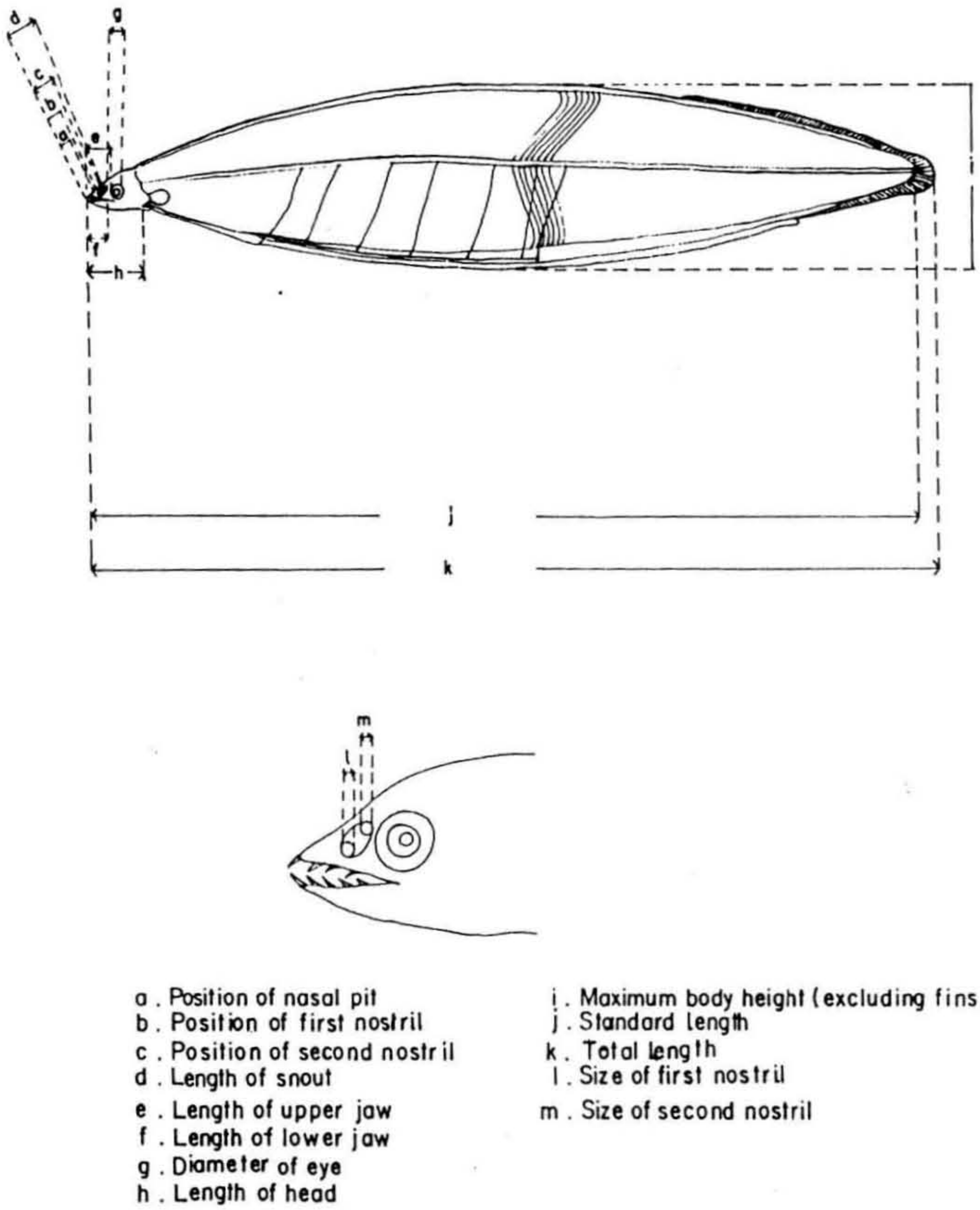
Pigmentation on leptocephali formed an important character for identification with its presence along the alimentary canal, head, body, fins etc. Another important character was the loops or swellings on the intestine, especially in the identification of Ophichthidae.

For the estimation in no/1000m^3, first the volume of water filtered is calculated from the area of the net and the area swept in 30minutes. From this the no/1000m^3 is found out for every counted sample from each station

$$\text{ie. no/1000m}^3 = \frac{\text{no*1000}}{\text{Vol. of water filtered}}$$

This is then converted into biomass in tones (t) in 1° square by taking into consideration the area of 1° square and the DSL thickness (in meters) for the respective stations.

Biomass in tones (t) in 1° square = no/1000m^3 * area of 1° square* DSL thickness



a . Position of nasal pit
b . Position of first nostril
c . Position of second nostril
d . Length of snout
e . Length of upper jaw
f . Length of lower jaw
g . Diameter of eye
h . Length of head
i . Maximum body height (excluding fins)
j . Standard length
k . Total length
l . Size of first nostril
m . Size of second nostril

Fig : 3 Leptocephalus – Morphometric measurements

Systematics

The first leptocephalus of record was collected in or shortly before 1763 by William Morris on the north coast of Wales. Gronow (1763) published the first description and gave it the name "Leptocephalus" though his work was later rejected for nomenclature purposes. For the next century, Leptocephali were treated as a distinct group of fishes. As new species were discovered they were placed either with in the genus *Leptocephalus* or into new genera. In 1861, Carus (1861a) mentioned about the small group of translucent fishes without reproductive organs, known especially from the Straits of Messina and generally called *Leptocephalidae*. He also set forth the theory that the leptocephalids were not adult fishes, but larval stages of other species, but was not able to refer them to definite adults. Gill (1864), was the first to suggest that the leptocephals were the larvae of eels ("Congers"), but the scientific proof was not given until Dareste (1873 b), showed that the so-called *Leptocephalus splanzani (= L. morrisii)* was a larval form of *Conger vulgaris*. Delage (1886) succeeded in keeping a Leptocephal alive in an aquarium so long that it metamorphosed into a young conger, thus proving that the Leptocephals are the larval stages of eel. Grassi and Calandruccio (1893), continued the experiments with other Leptocephals and proved with certainty that *Leptocephalus brevirostris*, described by Kaup (1856b), was the larval form of European fresh water eel, *Anguilla anguilla*,L.

General Description of Leptocephalus

Leptocephali are among the most distinctive of all larval fishes. They have an elongate, highly compressed, nearly transparent body with a series of 'V' or 'W' shaped myomeres covering most of the lateral surface (Fig.4). A transparent area extends dorsally and ventrally from the myomeres. They possess a small, laterally compressed head (hence the name leptocephalus = "slender head") with a series of strong, fang like, forwardly inclined teeth present on both upper and lower jaws. Dorsal, anal and pectoral fins are present in all leptocephali. In Anguilliformes, the dorsal and anal fins are long and continuous with a small, round caudal fin. Elopiform leptocephali have a large, forked caudal fin separate from the dorsal and

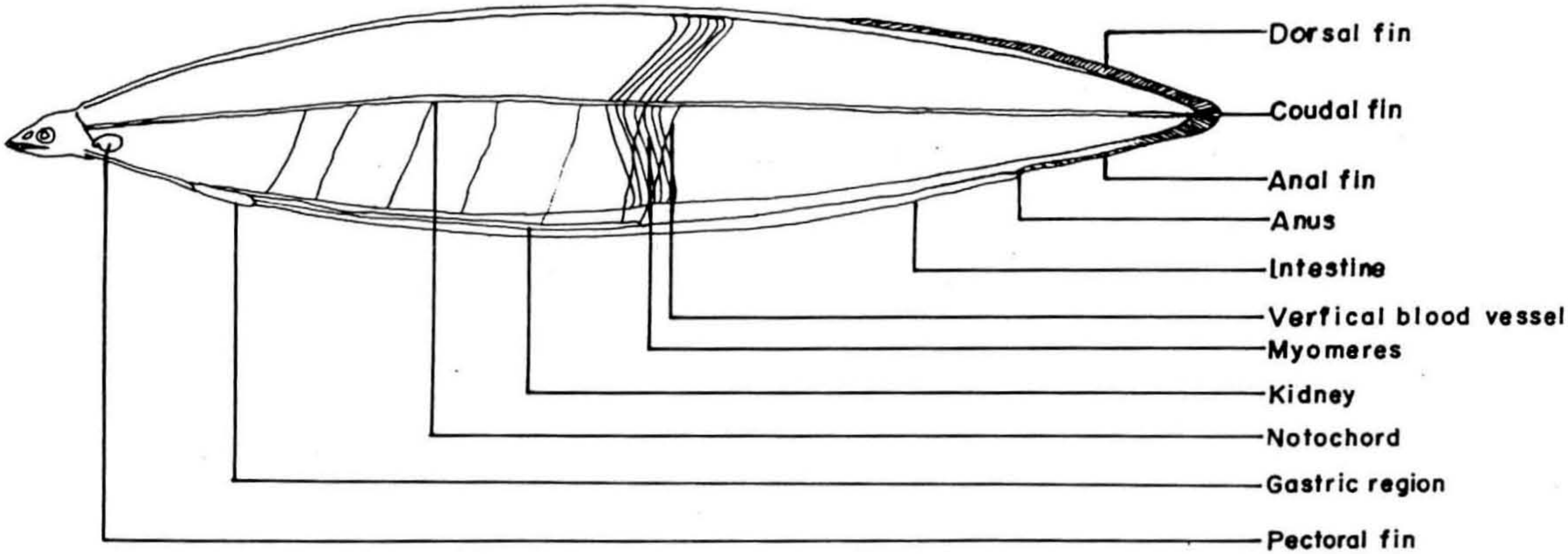


Fig. 4. Leptocephali – Body parts

anal fins and in the Notacanthiform, leptocephali it is in the form of a single filament. Hypural plates are present in all leptocephali, well before metamorphosis.

Most of the interior of the body is filled with an acellular mucinous material bounded by a continuous layer of epithelial cells. The mucinous pouch is the most characteristic feature of the leptocephalus. It separates the viscera, the notochord and the two sides of the body musculature from each other and gives form and rigidity to the body. The myomeres are thin and the skin is only a few cell layers in thickness.

The gut lies in the ventral margin. It is in the form of a simple, straight tube or may have swellings, arches or looped. The stomach is a rudimentary diverticulum at the point where the oesophagus and intestine meet. The liver and gall bladder are located near the same point. Liver may some times be extensive and divided into more than one lobe. The kidney (nephros) is a linear structure lying along the top of the gut. Gill arches are present but filaments do not appear until later in development.

The notochord runs through the middle of the body with the spinal cord lying above it and the dorsal aorta below. A series of vertical blood vessels extend between the dorsal aorta and the viscera, the posterior most entering the posterior end of the kidney. The heart is located beneath the anterior end of the oesophagus and in front of the pectoral fin. Although heart and blood vessels are present and functional, no haemoglobin is formed until metamorphosis. The eyes, olfactory organs and the portions of brain associated with them are well developed.

Living leptocephali are completely transparent except for the pigmentation on eye and body. Pigmentation is present in the form of melanophores. Melanin is present in the choroids of eye and in discrete melanophores distributed in characteristic patterns on head and body. A few leptocephali lack melanophores, but most have at least some.

One of the striking features of leptocephali is their large size. Lengths of 50 – 100 mm are common and some forms (Notacanthiformes (Nielsen and Larsen, 1970)) grow even much larger (1800 mm). They grow larger before metamorphosing than most other larval fishes. At metamorphosis, the leptocephalus shrinks, as the mucinous filler is lost.

World wide, leptocephali of Angulliform eels belonging to 16 families have been recognised so far, with many more unidentified leptocephali remaining. Smith (1979), published an exclusive guide with key, on the identification of leptocephali belonging to the three orders viz. Elopiformes, Anguilliformes and Notacanthiformes from the world oceans. The key is according to Smith (1979).

Key to Families

A1 Eye telescopic...B (Synaphobranchidae)
A2 Eye normal...C

B1 Intestinal pigment present; gut with several small thickenings; rostral filament sometimes present...Dysominae
B2 Intestinal pigment absent; gut a simple straight tube; rostral filament absent...Synaphobranchinae

C1 Head deep with elongate hyomandibula; gut with a single pigmented thickening at posterior end.....................................Saccopharyngoidei
C2 Head and jaw suspension normal...D

D1 Gut with one or more thickenings, loops or arches................................E
D2 Gut a simple straight tube without thickenings, loops or arches................H

E1 Gut with a single thickening or arch at posterior end................Moringuidae
E2 Gut with two or more thickenings or arches..F

F1 Gut with two thickenings....................................Nettastomatidae (Part)
F2 Gut with three or more thickenings or arches.....................................G

G1 Body very deep; myomeres about 80...................................Cyemidae
G2 Body moderately elongate; myomeres more than 100..............Ophichthidae

H1 Melanophores absent..Anguillidae
H2 At least some melanophores present..I

I1 Intestinal pigment absent...J
I2 Intestinal pigment present...L

J1 Pectoral fin greatly reduced; gut less than half standard length; dorsal and anal fin restricted to tip of caudal fin.......Muraenidae (in part: *Anarchias*)

J2 Pectoral fin well developed; gut more than half standard length; dorsal and anal fins not restricted to posterior tip of body................................K

K1 Last vertical blood vessel around myomeres 70-80; preanal myomeres more than 100..................................Derichthyidae: *Nessorhamphus*
K2 Last vertical blood vessel at myomeres 59-63; preanal myomeres 76-83...Derichthyidae: *Dericthys*
K3 Last vertical blood vessel at myomeres 30-37; preanal myomeres 89-125..Serrivomeridae

L1 Pectoral fin greatly reduced; posterior nostril above level of middle of eye; tail generally broadly rounded...Muraenidae
L2 Pectoral fin well developed; posterior nostril near or below level of middle eye; tail generally not broadly rounded..M

M1 Small but distinct deep-lying pigment spots along top of notochord; body elongate; ventral melanophores small, restricted to top of gut................ ....Nemichthyidae
M2 Not as above ....N

N1 Gut half standard length or less...O
N2 Gut greater than half standard length..P

O1 Body narrow and elongate; head elongate.. ....Nettastomatidae(in part: *Facciolella*)
O2 Body moderately deep; head moderately short.....................Xenocongrudae

P1 Head short and deep; no crescentic patch of pigment below eye.................. ....Heterenchelyidae
P2 Head generally moderately elongate, snout more or less acute; those with short heads generally have crescentic patch of pigment below eye............... ....Congridae (including Muraenesocidae)

In the present study, leptocephali belonging to five families viz. Congridae, Muraenidae, Nemichthyidae, Ophichthidae and Synaphobranchidae of the order Angulliformes have been identified up to genus and species level.

The Indian works are mostly from the collections made from the coastal waters and the present study being done on deep-sea collections, Lat. $6^0 - 14^0$ N, Long. $67^0 - 77^0$E and bottom depth 180 – 4600m, from the southwest coast of India. (Aiyar *et al.*, 1944; Nair, 1946, 1947,1948; Gopinath 1946,1950; Nair and Bhimachar, 1950; Jones and Pantulu, 1952, 1955; Pantulu and Jones, 1954; Nair and

Mohamed, 1960 a- e). Since the work done on Indian leptocephali is scarce some of the genus has been tentatively identified based on the number of vertebrae.

The descriptions on the leptocephali of the five families are presented.

Family - Congridae

This is one among the largest of the eel families having wide variations in almost all important characters. The congrid leptocephali can be recognised from the following characters: body moderate to elongate; head and snout moderately short to moderately elongate; tail variable from very long to very short; ventral pigment variable but always present; lateral pigment variable, some times absent; maximum size variable, about 90 – 300mm in some species, most species probably reach close to 100mm.

***Ariosoma* type – Exterilium larva**

Specimens examined = 37; total length = 40-192mm; maximum body height (excluding vertical fins) = 15mm; length of head = 6mm; length of snout = 2.04mm; diameter of eye = 1.47mm; position of nasal pit = 1.38mm; position of first nostril = 1.41mm; size of first nostril = 0.16mm; position of second nostril = 1.86mm; size of second nostril = 0.19mm; total myomeres = 140-146; pre anal myomeres = 137; post anal myomeres = 7; origin of dorsal fin = 132nd myomere; dorsal fin rays = 44; anal fin rays = 42; caudal fin rays = 6+3; teeth = I+I+6+21 / I+9+9.

Moderate large leptocephali with long, broadly compressed body tapering to both ends; head moderately large (Plate1. a); snout bluntly pointed, with a concave constriction near the nasal organ; cleft of mouth straight, slightly oblique, reaching just near the centre of the eye; nasal region well developed with anterior and posterior nostrils separate; eye large and circular; larva with well defined dentition on each of its jaws (Plate1. b): the each half of upper jaw is provided with a short, antero-dorsal tooth above the long curved fang like grasping tooth followed by six large, pointed teeth and 21 closely arranged small teeth; lower jaw on its each half with a slightly curved, pointed grasping tooth, followed by nine large teeth and nine forwardly curved small teeth; pectoral fin oval with poorly developed rays; dorsal and anal fins restricted to the posterior with well defined rays, posterior most rays larger in comparison with the anterior ones; origin of dorsal fin slightly ahead of the anal fin origin; caudal fin with 9 well developed long rays on the two distinct hypurals (Plate1. e); intestine, long straight without loops or swellings, reaching to more than $3/4^{th}$ of the body length and also trailing outside the body, outer part of which accounting for more than half the length of body.

Head of the larva with out any pigmentation; no pigmentation below eye; a few, scattered, stellate melanophores in and around the heart region; a mid dorsal row of scattered, stellate chromatophores starting from the 14^{th} myomere continuing posteriorly where it becomes more scattered and discontinuous well before the dorsal fin origin; lateral pigmentation in the form of closely packed, small, stellate chromatophores (numbering 2 to as many as 23) forming oblique lines outlining the myosepta (Plate1. c), starting from the 7^{th} myosepta and continuing till the last; a row of scattered, stellate chromatophores commencing from a region below the pectoral fin base on the ventral side of the gut anterior to the gastric region after which it becomes paired and switches over to the dorsal side of the intestine (Plate1. d) continuing till the tip of the outer intestine; all fin rays with pigments on its base except for a few anterior most dorsal and anal fin rays; no pigmentation on pectoral fin.

***Congrellus anago* (non Temm. and Schleg.)**

Specimens examined = 21; total length = 90-157mm; maximum height (excluding vertical fins) = 13mm; length of head = 4mm; length of snout = 1.22mm; diameter of eye =1.12mm; position of nasal pit = 0.70mm; position of first nostril = 0.74mm; size of first nostril = 0.1mm; position of second nostril = 1.02mm; size of second nostril; total myomeres = 112-118; pre anal myomeres = 106; post anal myomeres = 12; origin of dorsal fin = 106^{th} myomere; dorsal fin

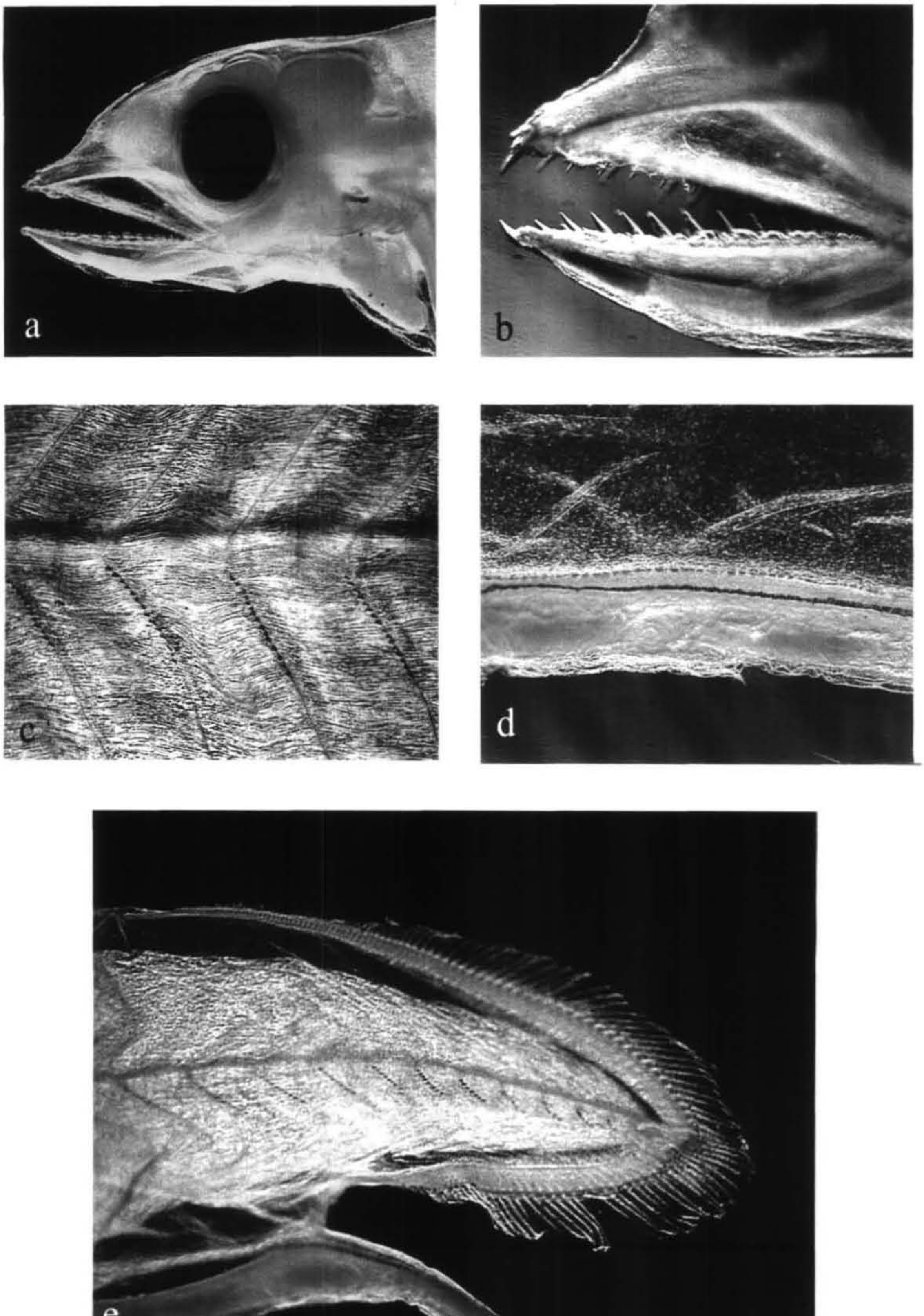


PLATE 1. Congridae - *Ariosoma* type - Exterillium larva
a. Head b. Teeth c. Lateral pigmentation
d. Pigmentation on dorsal side of intestine
e. Tail

rays = 47; anal fin rays = 50; caudal fin rays = 3+3; teeth = I+10+8 / I+10+4.

Body long, flattened, relatively broad and slightly tapering towards head and tail; head small (Plate2. a); snout triangular and bluntly pointed; cleft of mouth oblique, slightly curved, reaching up to the middle of eye; nasal organ developed with well differentiated nostrils; both jaws of the same length; prominent, large, circular eye; dentition very prominent on each half of both the jaws (Plate2. b): tip of upper jaw with a very prominent, sharply pointed tooth, ten large teeth decreasing in length anteriorly and posteriorly with the third tooth being the longest followed by 8 small closely packed teeth; in the lower jaw single curved tooth arising from just below the tip followed by ten large teeth and four small teeth; pectoral fin small, round with feeble rays; both dorsal and anal fins are restricted to the posterior with same level of origin (Plate2. f); posterior most rays of dorsal and anal fins longer in comparison with the anterior ones; caudal fin with six long and distinct rays; hypurals well developed; intestine long; straight, more than 3/4th length of body, opening at 106th myomere.

Head devoid of any pigmentation; a few scattered; stellate chromatophores beneath the heart (Plate2. c); a mid dorsal row of stellate chromatophores starting from 13th myomere, continuing posteriorly and become discontinued a distance before the origin of dorsal fin; lateral pigmentation in the form of a row of minute pigments numbering 3 to as many as 21, outlining the myosepta, starting from the 13th myosepta onwards to the last, giving the appearance of short, oblique lines (Plate2. d); a row of closely packed, stellate chromatophores on the ventral side of gut anterior to the gastric region, posterior to which it shifts to the dorsal side of the intestine (Plate2. e) and continuing till the anus; pigmentation on the base of all caudal fin rays and anal fin rays, except for a few anterior most anal fin rays; dorsal fin with pigmentation only on the base of posterior most long fin rays; pectoral fin with out pigmentation.

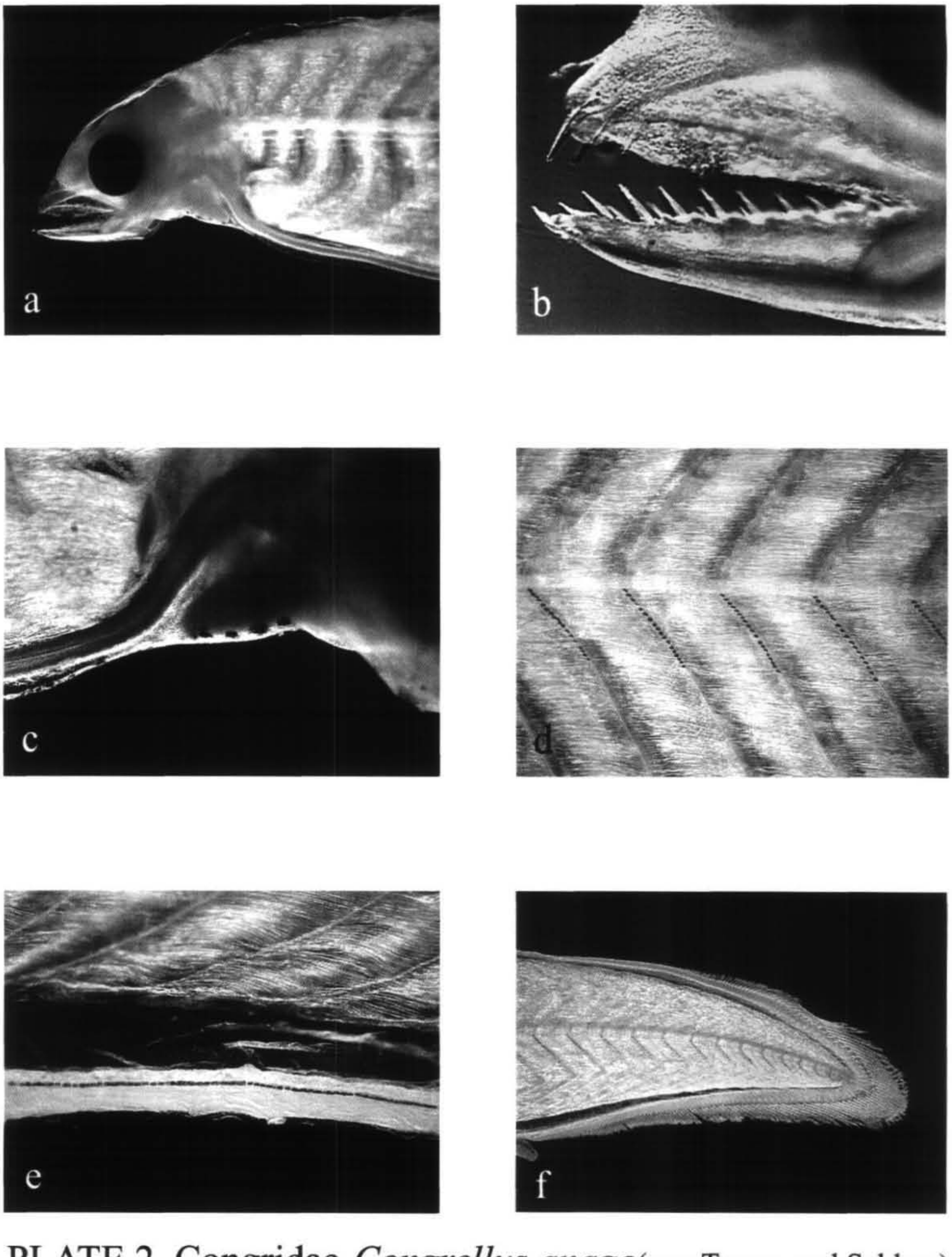


PLATE 2. Congridae-*Congrellus anago*(non Temm. and Schleg.)
a. Head b. Teeth c. Pigmentation beneath heart
d. Lateral pigmentation e. Pigmentation on
dorsal side of intestine f. Tail

***Uroconger lepturus* (Richardson)**

Specimens examined = 39; total length = 50-129mm; maximum body height (excluding vertical fins) = 8mm; length of head = 4mm; length of snout = 1.28mm; diameter of eye = 1.34mm; position of nasal pit = 0.32mm; position of first nostril = 0.35mm; size of first nostril = 0.16mm; total myomeres = 152-220; pre anal myomeres = 167; post anal myomeres = 43; origin of dorsal fin = 55^{th} myomere; dorsal fin rays = 140; anal fin rays = 75; caudal fin rays = 4+3; teeth = I+I+7+14 / I+15.

Body elongate, transparent and moderately high, tapering posteriorly to a long, pointed tail; head very short and triangular (Plate3. a); nasal organ well developed with only the anterior nostril discernible (in the specimen examined); eye prominent and slightly oval; cleft of mouth oblique and extends to the middle of the eye; upper jaw marginally longer than the lower jaw; both jaws provided with pointed, forwardly directed teeth (Plate3. c)- each half of the upper jaw with single, antero-dorsally placed, short, grasping tooth followed by a very long , slightly curved, acute tooth; rest of the teeth arranged in two groups: first group composed of seven moderately long, pointed teeth and the second group have 14 small, closely arranged teeth in the posterior half of upper jaw; lower jaw possesses on its each half a slightly curved, pointed grasping tooth placed just below its tip followed by 14 fairly long teeth decreasing in height posteriorly; branchiostegal rays discernible (approx.11), curving towards the opercular region; pectoral fin large, circular to oval with indistinct rays (Plate3. d); dorsal fin long, well developed with distinct rays, origin of dorsal fin (55^{th} myomere) very much ahead of the anal fin origin; anal fin short in comparison with dorsal fin but with discernible rays, though less developed than the dorsal fin rays; posterior most rays of both dorsal and anal fins longer in comparison with the anterior ones; caudal fin with 7 very long, clearly distinct rays (Plate3. g); hypurals well developed; alimentary canal long, straight and opens below 167^{th} myomere.

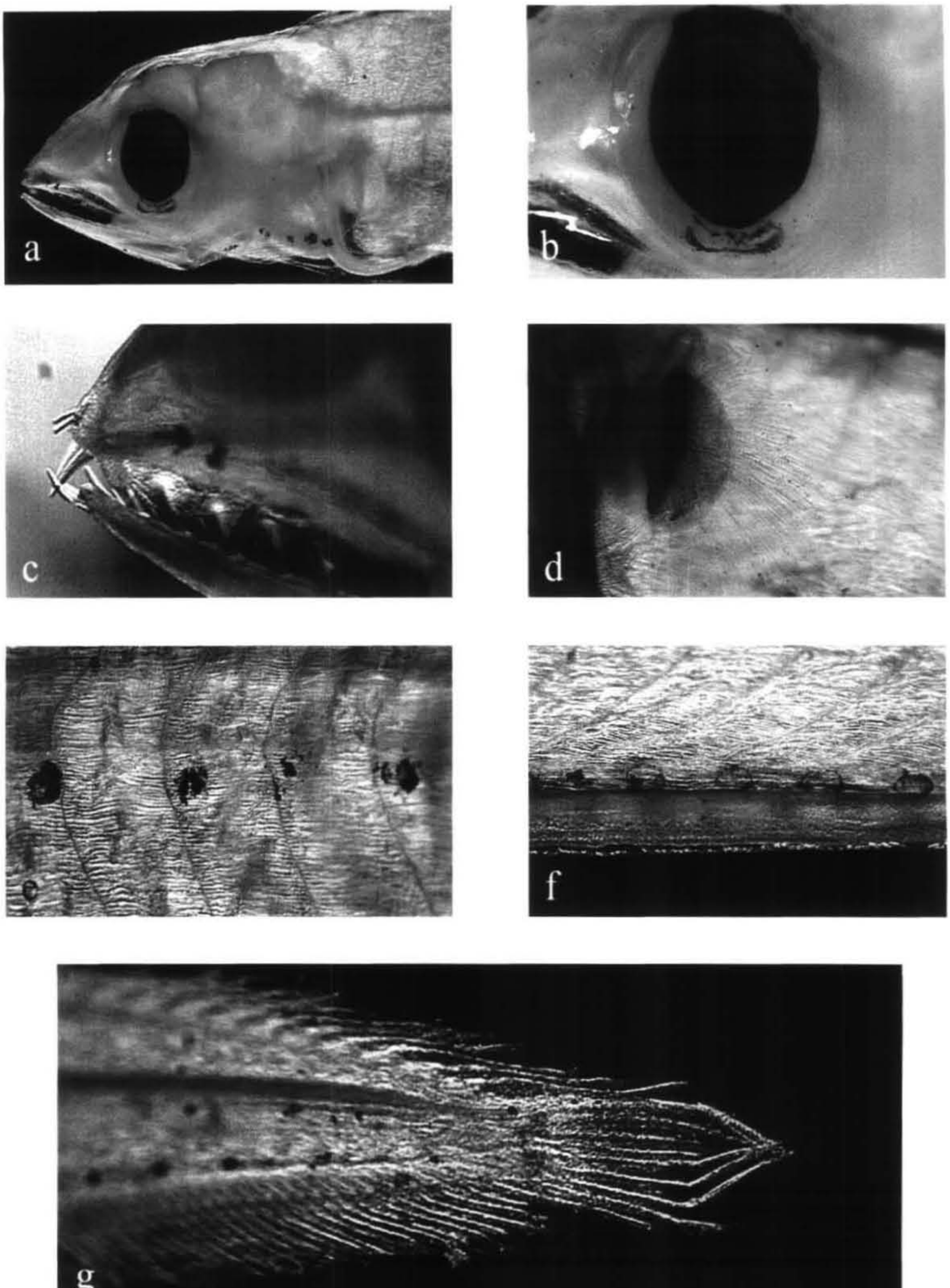


PLATE 3. Congridae-*Uroconger lepturus* (Richardson)
a. Head b. Pigmentation below eye c. Teeth
d. Pectoral fin e. Lateral pigmentation
f. ventral pigmentation g. Tail

Pigmentation in the larva is very conspicuous: two distinct pigment spots on the anterior margin of the upper jaw; group of chromatophores below the eye (crescent shaped) (Plate3. b); curved pigment patch above the eye; near the heart 6-7 black pigments cells are present – apart from the above described pigmentation rest of the head is devoid of any pigments; pigmentation on the body of the larva as follows: a mid lateral row of large, round, unbranched, black chromatophores – starting from 12^{th} myomere onwards (Plate3. e), occurring regularly on all myomeres with occasional absence on some, become discontinuous towards tail; a similar row of chromatophores present ventrally on the dorsal side of the alimentary canal (Plate3. f), continuing to the post anal region, just above the base of anal fin where it becomes slightly scattered; all the fin rays without any pigmentation.

Type A

Specimens examined = 27; total length =30-188mm; maximum height (excluding vertical fins) = 7mm; length of head = 3mm; length of snout = 0.99mm; diameter of eye = 0.74mm; position of nasal pit = 0.52mm; size of first nostril = 0.13mm; position of first nostril = 0.55mm; total myomeres =115-128; pre anal myomeres = 111; post anal myomeres = 9; teeth = I+I+3+6 / I+3+6.

Body elongate, gradually tapering towards tail than head; head small (Plate4. a); snout conical, moderately pointed; cleft oblique, slightly curved, reaching to the middle of eye; nasal organ developed with only the anterior nostril discernible; eye circular and prominent; each half of the upper jaw with a slender, antero-dorsal tooth (Plate4. b), a pointed, slightly curved large tooth followed by three moderately large teeth and group of six large teeth in the posterior part; lower on its each half is provided with an upwardly curved, sharp tooth originating from just below the tip followed by three large teeth and six comparatively large teeth; pectoral fin small with poorly developed rays; dorsal and anal fins restricted to the posterior; caudal fin poorly developed; fin rays on dorsal, anal and caudal fin not distinct (Plate4. d); hypurals distinct; intestine long, straight with out any loops.

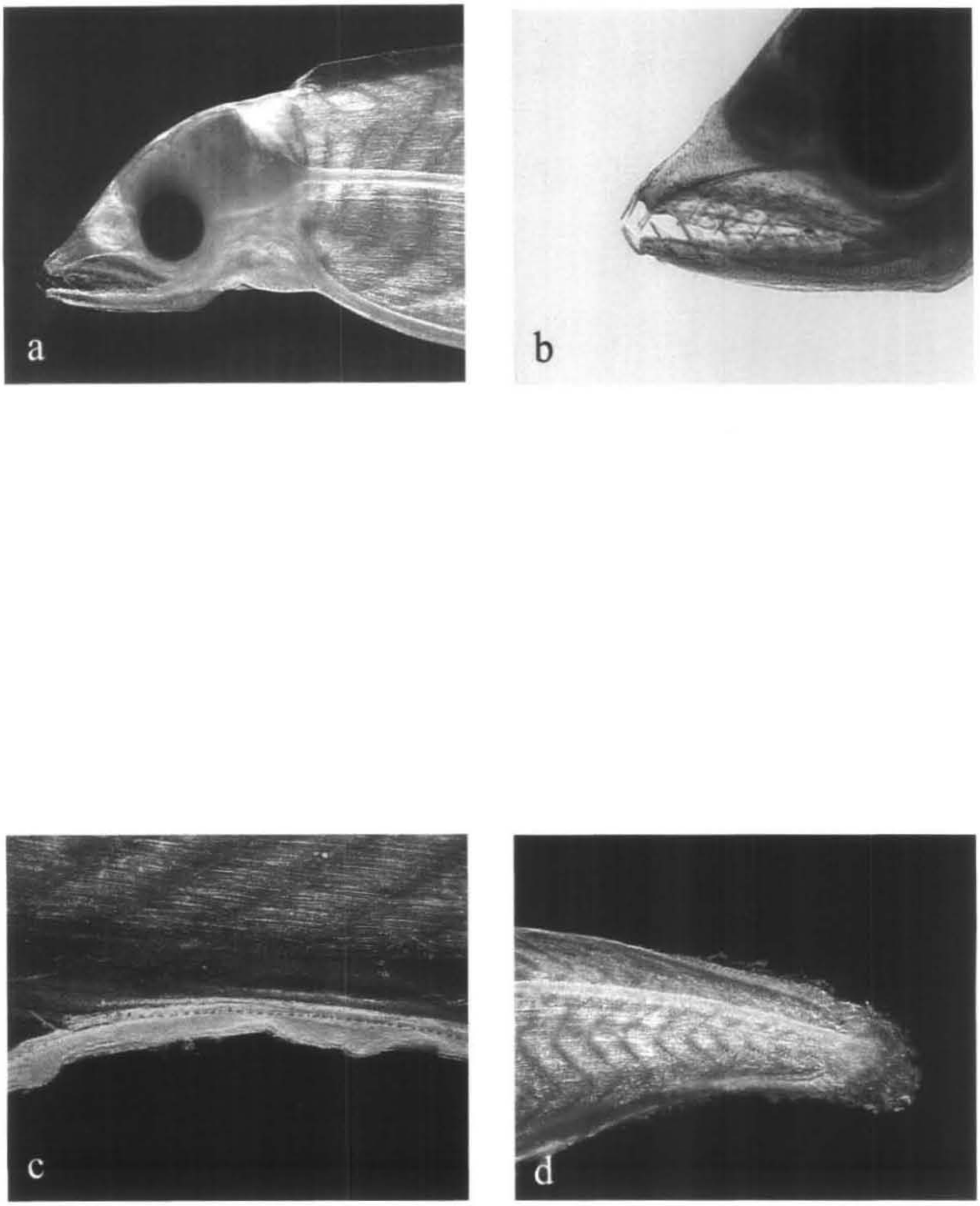


PLATE 4. Congridae-Type A
a. Head b. Teeth c. Pigmentation on dorsal side of intestine d. Tail

A mid dorsal row of stellate chromatophores, starting from the level of 5th myomere and reaching up to the origin of dorsal fin; a row of pigment spots outlining the myosepta just below the mid lateral line forming a series of short diagonal lines from head to tail; a ventral row of chromatophores on the gut anterior to the gastric region, posterior to which it shifts to the dorsal side of the intestine (Plate4. c); majority of the dorsal, anal and caudal fin rays with pigmentation on its base; head, heart and pectoral fins with out any predictable pigmentation.

Type B

Specimens examined = 2; total length = 56-58mm; maximum height (excluding vertical fins) = 6mm; length of head = 3mm; length of snout = 1.25mm; diameter of eye = 0.74mm; position of nasal pit = 0.8mm; total myomeres = 136-138; pre anal myomeres = 131; post anal myomeres = 7; origin of dorsal fin = 126th myomere; teeth = I+3+6 / I+3+6.

Body long with a moderately pointed tail; head small (Plate5. a) with a bluntly pointed snout; cleft of mouth slightly oblique, reaching to the middle of the eye; both jaws of the same length; eye sub circular; nasal organ well developed with out discernible nostrils; a prominent constriction near the nasal organ; dentition on each half of the jaw as follows: upper jaw with a slender, antero-dorsal tooth followed by three large teeth and six small teeth; single upwardly curved tooth originating just below the tip, three comparatively large teeth increasing in length posteriorly, six small teeth are present on the lower jaw; pectoral fin slightly oval with indistinct rays; dorsal and anal fins restricted to the posterior, with feeble rays; hypurals well developed (Plate5. e) though caudal fin very feeble; intestine long, straight with out loops or swellings reaching more than 3/4th the length of body, opening below 131st myomere.

A row of closely packed pigment spots above the eye (Plate5. b); a few scattered chromatophores on the dorsal side; row of pigment spots outlining the myosepta immediately below the midline forming a series of oblique lines from the

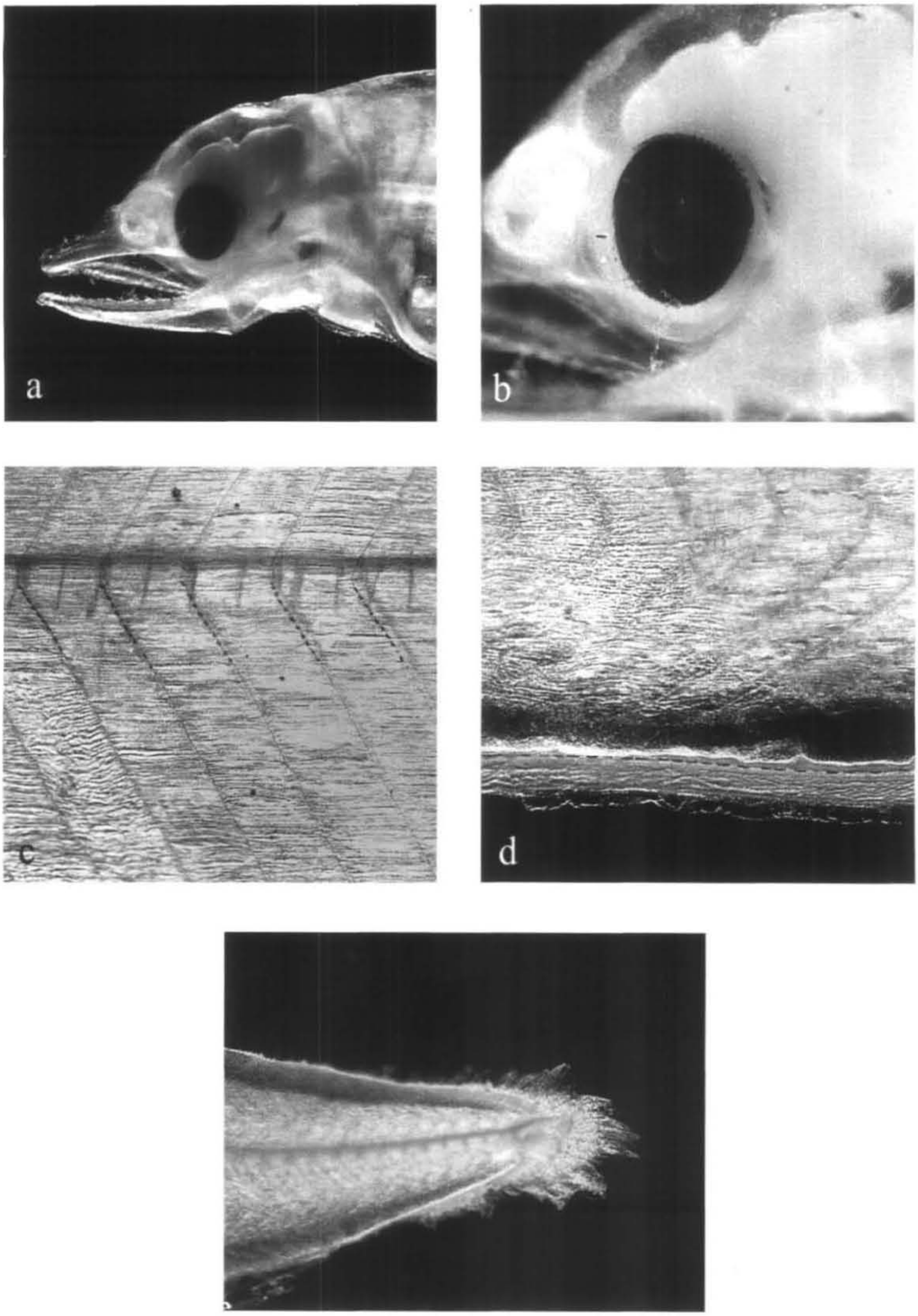


PLATE 5. Congridae-Type B
a. Head b. Pigmentation on eye c. Lateral pigmentation d. Pigmentation on dorsal side of intestine e. Tail

12th myosepta onwards (Plate5. c); a row of closely arranged ventral melanophores below the gut anterior to the gastric region posterior to which it shifts to the dorsal side of the intestine (Plate5. d); posterior most anal fin rays with pigmentation at its base; caudal fin, dorsal fin and pectoral fin with out pigmentation.

Family - Ophichthidae

Ophichthid larvae can be recognized by the arches or swellings in the gut, but a few forms are known in which these intestinal modifications are inconspicuous. The looped or swollen intestine is a larval character, which does not carry over into the juvenile ophichthid.

Ophichthid leptocephali have a moderately elongate and shallow body, acute snout. Tail moderate to blunt with caudal fin reduced or sometimes absent with the tail pointing out. Pectoral fin usually small, rounded or sometimes minute. Gut formed about one- half to two- thirds of standard length, with a variety of thickenings and/or arches or looped (festooned), ranging from three to sixteen equally spaced points, sometimes accompanied by the swellings of the pronephric ducts and are pigmented. Liver lobed sometimes with two or three connected or separate lobes.

Pigmentation often conspicuous, consisting of patches of minute chromatophores, occurring occasionally on the head, jaws etc. Lateral pigmentation variable – present along the midline in the form of a row of pigment patches – cutaneous or subcutaneous, pre anal or post anal and some times a combination of all or may be present in the form of a outlining of minute melanophores on the myosepta forming a series of diagonal lines just below the midline or as streaks of pigment on myosepta. Ventral pigmentation tends to be concentrated on the intestine mostly on the intestinal thickenings and arches. Pigmentation also on the bases of the anal and dorsal fins. Myomeres ranges from 120 to 270; total length range from 50 mm – 180 mm.

Ophichthus sp.

Specimens examined = 2; total length = 61-104mm; maximum body height (excluding vertical fins) = 5mm; length of head = 5mm; length of snout = 1.41mm; diameter of eye = 0.8mm; position of nasal pit = 0.74mm; total myomeres = 154-158; pre anal myomeres = 65; post anal myomeres = 93mm; origin of dorsal fin = 30th myomeres; dorsal fin rays = 62; anal fin rays = 218; teeth = I+6+6 / I+7+3.

Body elongate, compressed, tapering after the mid point of the post anal region; head slightly elongate to blunt (Plate6. a); snout less conical to round; nasal organ well developed, nostrils not differentiated; eye circular; cleft of mouth oblique, slightly curved, extending to the middle of the outer margin of eye; teeth sharp (Plate6. b), in three groups on each side of the upper jaw and in three groups on each side of the lower jaw as follows: in the upper jaw a fang like tooth followed by six large teeth and six smaller teeth; approximately 26 branchiostegal rays observed, continuing over the opercular region; pectoral fin more or less rounded with feeble rays; dorsal fin with only the posterior most rays discernible; anal fin with distinct rays; caudal fin absent, tail ending in a bluntly pointed tip (Plate6. g); intestine slightly shorter than half the total length, looped or festooned (Plate6. e) with 8 humps between adjacent loops; liver with two connected lobes (Plate6. f).

Pigmentation pattern as follows: a series of pigment spots along the margin of the upper jaw; group of pigments between the outer and inner margin of eye (Plate6. c); group of closely packed stellate chromatophores on the base of pectoral fin; lateral pigmentation as follows: single row of closely packed, stellate, branched chromatophores outlining the myosepta just below the midline, starting from myosepta 8 with irregular distribution; ten widely placed pigment patches below the midline in the post anal region (Plate6. d); cluster of pigments near the caudal region; closely packed, stellate, branched chromatophores on the dorsal side of all the eight humps of the looped intestine, a few on the base of posterior most dorsal fin rays; and on the base of all anal fin rays.

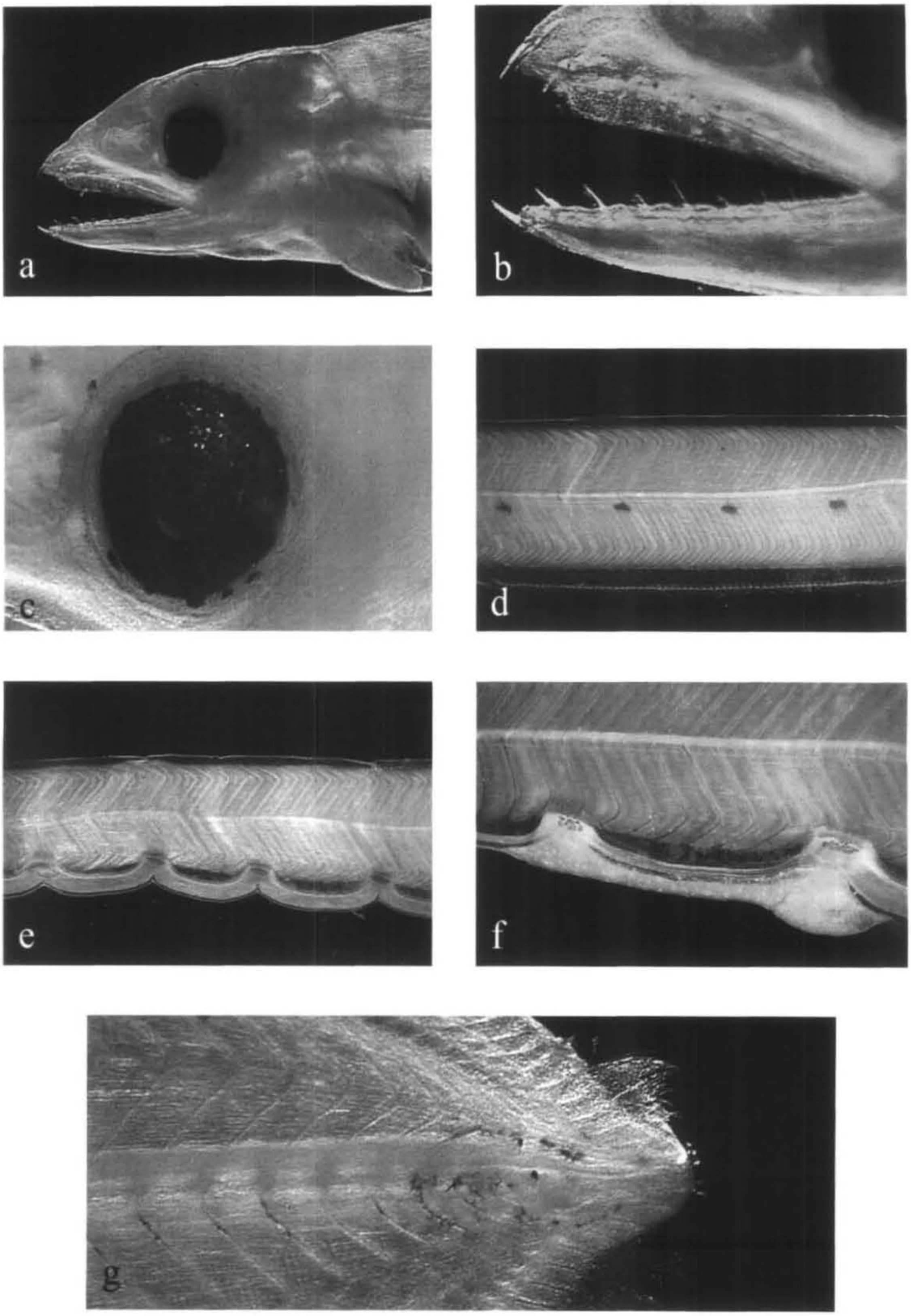


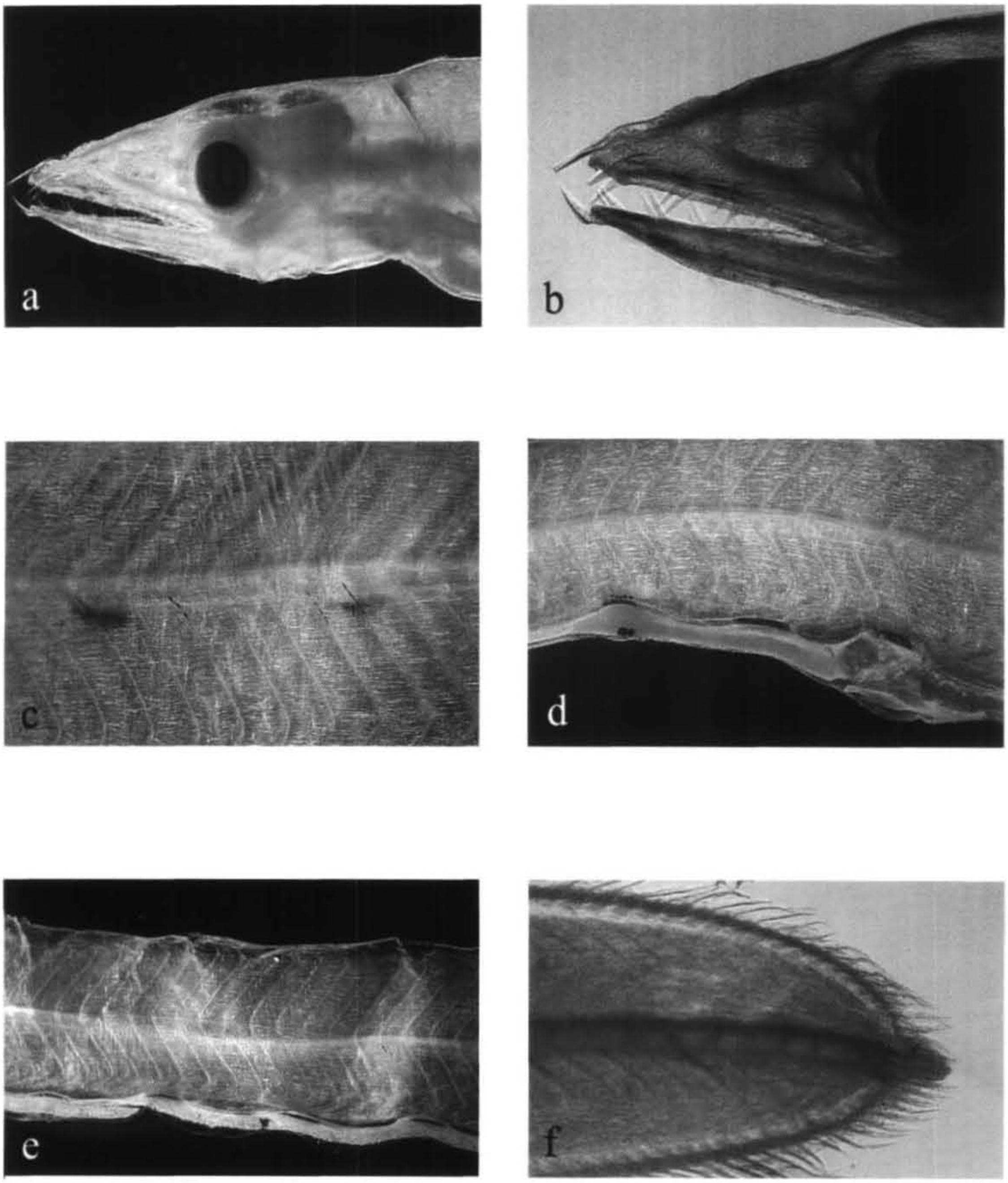
PLATE 6. Ophichthidae-*Ophichthus* sp.
a. Head b. Teeth c. Pigmentation on eye
d. Lataeral pigmentation (post anal) e. Intestine
f. Liver g. Tail

Ophisurus sp.

Specimens examined = 2; total length = 105-113mm; maximum body height (excluding vertical fins) = 2mm; length of head = 4mm; length of snout = 1.28mm; diameter of eye = 0.61mm; position of nasal pit = 0.64mm; total myomeres = 220-223; pre anal myomeres = 79; post anal myomeres = 141; origin of dorsal fin = 22nd myomeres; dorsal fin rays = 57; anal fin rays = 342; teeth I+ I+ 5+5 / I+6+5.

Body long, compressed and shallow; tapering towards the posterior after the midpoint; head elongate (Plate7. a) and well differentiated from the trunk; snout sharply conical; nasal organ well developed, with two nostrils not yet separated; eye sub circular; cleft of the mouth oblique, straight extending to below the outer margin of the eye; teeth relatively acute (Plate7. b), in four groups on each side of the upper jaw and in three groups on each half of the lower jaw as follows: in the upper jaw a relatively slender clasper like antero- dorsal tooth, a single fang like tooth followed by a series of six large teeth and five smaller teeth; branchiostegal rays not clear; pectoral fin short with indistinct rays; dorsal fin well developed originating from myomeres 22, except for the posterior most rays the anterior ones are not discernible, ending sub terminally; anal fin also well developed with conspicuous rays; caudal fin absent and the tail protrudes out as free pointed tip (Plate7. f); liver with two connected lobes (Plate7. d); intestine less than half the total length with 17 prominent swellings (Plate7. e).

Pigmentation occurring invariably along various positions on the body, in detail, as follows: two streaks of chromatophores on the middle of the margin of upper jaw; two pigment spots near the tip of lower jaw; a vague pigment patch on the base of pectoral fin; streaks of pigment on the myosepta just below the midline, starting from the 22nd myomeres, with no regularity in its occurrence; post anal region with 29 internal pigment patches just below the midline (Plate7. c); closely packed stellate chromatophores on the dorsal side of the 17 prominent swellings of the gut; dorsal fin devoid of any pigments on the bases of its rays; majority of the bases of anal fin rays have pigmentation; cluster of pigments near the caudal region.



PALTE 7. Ophichthidae-*Ophisurus* sp.
a. Head b. Teeth c. Lateral pigmentation (post anal) d. Liver e. Intestine f. Tail

Phaenomonas sp.

Specimens examined = 1; total length = 93mm; maximum body height (excluding vertical fins) = 6mm; length of head = 5mm; length of snout = 1.8mm; diameter of eye = 0.8mm; position of nasal pit = 1.02mm; total myomeres = 273; pre anal myomeres = 87; post anal myomeres = 186; origin of dorsal fin = 48^{th} myomere; dorsal fin rays = 20; anal fin rays = 324; teeth = I+(5+3)+7 / I+8+3.

Body elongate, tapering posteriorly to a pointed tail; head moderately elongate (Plate8. a); snout conical; nasal region well developed without distinctive anterior and posterior nostrils; eye circular; cleft of mouth straight, extending behind the centre of the eye; teeth in three groups on each half of the upper jaw and in three groups on each half of the lower jaw as follows (Plate8. b): a fang like forwardly directed tooth in the front followed by eight larger teeth (of which the posterior three are comparatively smaller than the anterior five) and seven much smaller teeth; lower jaw with single forwardly directed tooth followed by eight larger teeth and three smaller teeth; branchiostegal rays present (more than 11); pectoral fin round; dorsal fin with only the posterior most rays distinct; anal fin with fully developed rays; caudal fin present with four distinct rays (Plate8. f); liver with three separate lobes (Plate8. e); intestine heavily looped or festooned (Plate8. d), with eight swellings or humps at the angle between adjacent loops.

Pigmentation on the larva is as follows: row of pigment spots on the posterior margin of the upper jaw; cluster of pigments near the tip of lower jaw; a few pigment spots behind the eye on the hind brain; group of internal pigment spots anterior to heart; pigment spots near the base of pectoral fin; lateral pigmentation in the form of closely packed, stellate, branched chromatophores outlining the myosepta with no regularity; ten widely placed internal pigment patches below the mid lateral line in the post anal region (Plate8. c); large cluster of pigments near the caudal region; closely packed, stellate, branched chromatophores on the dorsal side of eight thickenings of the highly looped intestine; pigments on the bases of a fewer dorsal fin rays; most of the anal fin rays with pigments at its base.

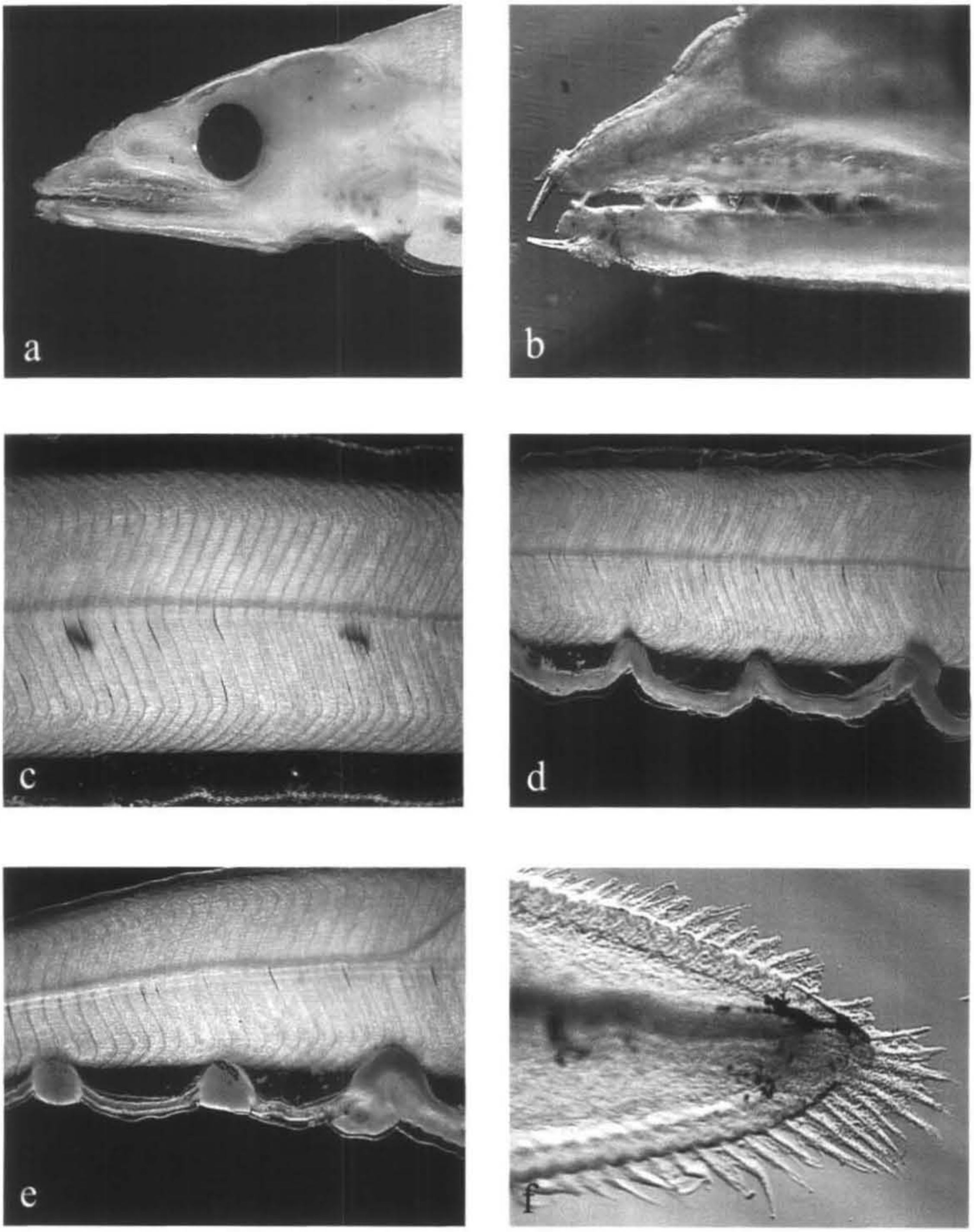


PLATE 8. Ophichthidae- *Phaenomonas* sp.
a. Head b. Teeth c. Lateral pigmentation (post anal) d. Intestine e. Liver f. Tail

Type A

Specimens examined = 4; total length = 77-89mm; maximum body height (excluding vertical fins) = 7mm; length of head = 5mm; length of snout = 1.34mm; diameter of eye = 0.8mm; position of nasal pit = 0.45mm; total myomeres = 129-131; pre anal myomeres = 66; post anal myomeres = 65; origin of dorsal fin = 60th myomere; dorsal fin rays = 137; anal fin rays = 162; teeth = I+I+6+6 / I+9

Body compressed, elongate with more or less uniform height; posterior part tapering to a rather bluntly pointed tail; snout bluntly pointed (Plate9. a); upper jaw slightly longer than the lower jaw; nostrils not distinct; cleft straight, extending behind the middle of the eye; eye slightly oval; well developed sharp teeth on both jaws as follows: in upper jaw four groups of teeth – an antero-dorsal tooth, a fang like tooth, followed by six large teeth and six comparatively smaller teeth; in lower jaw two sets of teeth – a fang like teeth in the front followed by nine teeth which gradually decrease in size posteriorly; branchiostegal rays distinct (more than 21) continuing upwards over the opercular region; pectoral fin well developed though with indistinct rays; dorsal and anal fins well developed with distinct rays; caudal fin absent and the tail protrudes out as a free pointed tip (Plate9. d); hypurals well developed; liver with two connected lobes (Plate9. c); intestine slightly more than ½ the total length, looped (Plate9. b) with nine humps or thickenings between each loop.

Pigmentation was very prominent in the larva and is described as follows: two pigment spots on the anterior margin of the upper jaw; closely packed, branching chromatophores near the base of pectoral fin; six internal pigment patches in the post anal region below the midline; minute widely placed pigment spots numbering 1to5 outlining the myosepta just below the midline starting from the 11th myosepta onwards; where the internal patches are present, they appear as closely packed and branched, giving the appearance of streaks or lines on the myosepta; a small cluster of pigments near the caudal tip; pigmentation above the nine thickenings on the intestine as follows: chromatophores on the first thickening are closely packed and form a

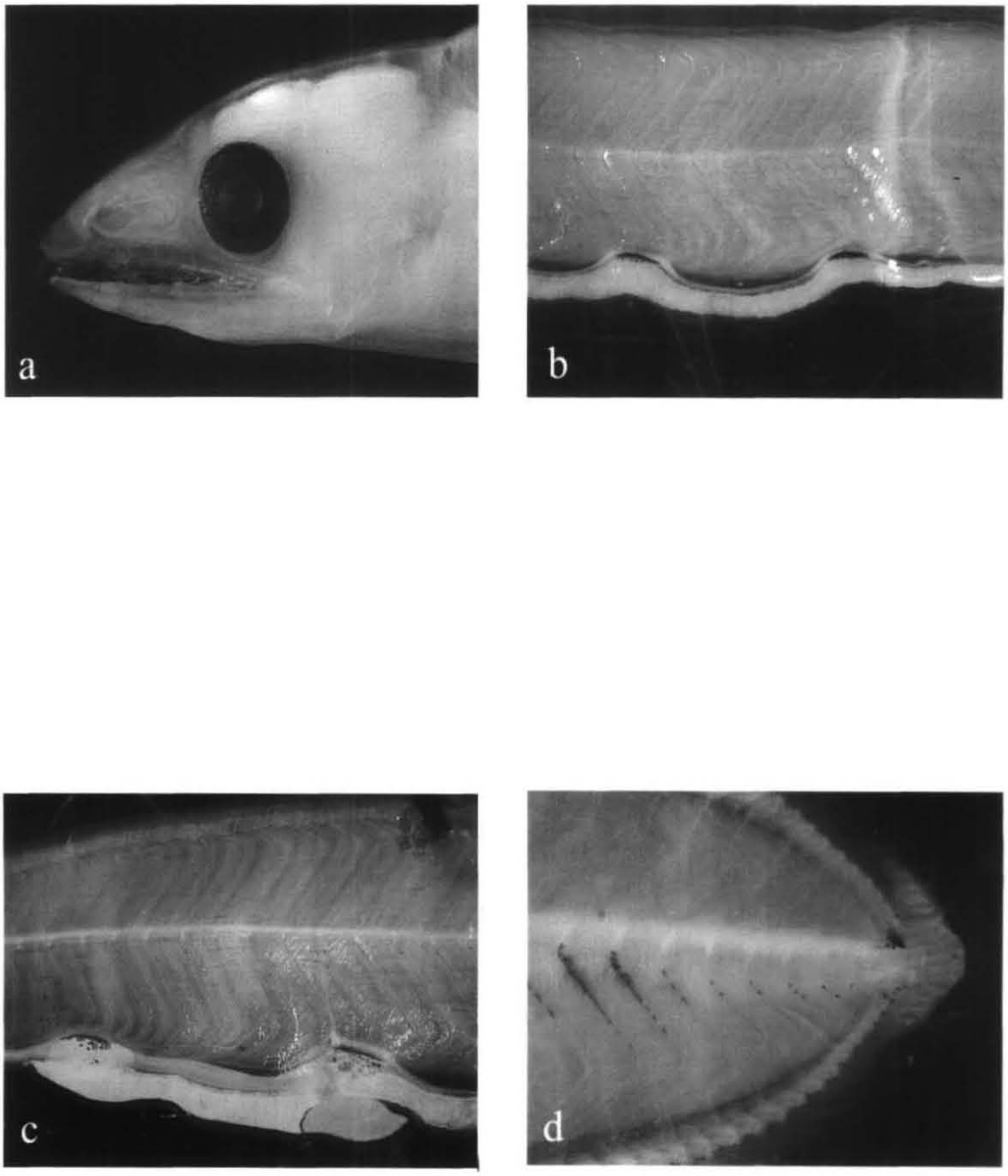


PLATE 9. Ophichthidae-Type A
a. Head b. Intestine c. Liver d. Tail

hexagonal, honey comb like pattern; chromatophores above the rest of the thickenings are stellate, branched and closely packed; dorsal fin rays devoid of any pigments on its base; all anal fin rays with pigmentation on its base.

Type B

Specimens examined = 1; total length = 46mm; maximum height (excluding the vertical fins) = 4mm; length of snout = 1.28mm; diameter of eye = 0.67mm; position of nasal pit = 0.77mm; total myomeres = 149mm; pre anal myomeres = 81mm; post anal myomeres = 68mm; origin of dorsal fin = 56th myomere; teeth = I+I+4+5 / I+6+3.

Body elongate, tapering gradually towards the posterior after the midpoint ending in a bluntly pointed tail; head elongate (Plate10. a) and well differentiated from trunk; snout conical; lower jaw slightly longer than the upper jaw; nasal organ well developed with the nostrils not yet separated; cleft of mouth slightly oblique, curved, reaching beyond the middle of the eye; eye oval; each half of both the jaws with acute teeth as follows (Plate10. b): upper jaw with four groups of teeth – a large antero-dorsal tooth followed by a fang like tooth, four large teeth and five smaller teeth; lower jaw with a single, large almost horizontally placed tooth in the tip, six large teeth followed by three smaller teeth; branchiostegal rays not visible; pectoral fin with feeble rays; dorsal and anal fins with indistinct rays; caudal fin absent and tail freely protrudes out (Plate10. e); hypurals well developed; intestine nearly 3/4th length of body, highly looped (Plate10. d)with nine humps or thickenings between adjacent loops; liver with two connected lobes (Plate10. c).

Pigmentation very conspicuous in the leptocephalus and described as follows: three pigment spots on the margin of the upper jaw; a less conspicuous pigment patch on the base of the pectoral fin; five internal pigment patches in the post anal region below the mid lateral line; streaks of pigment present above the patches and on the last three myosepta; pigment clusters near the caudal region; highly branched, stellate, closely packed group of chromatophores above the nine intestinal humps or

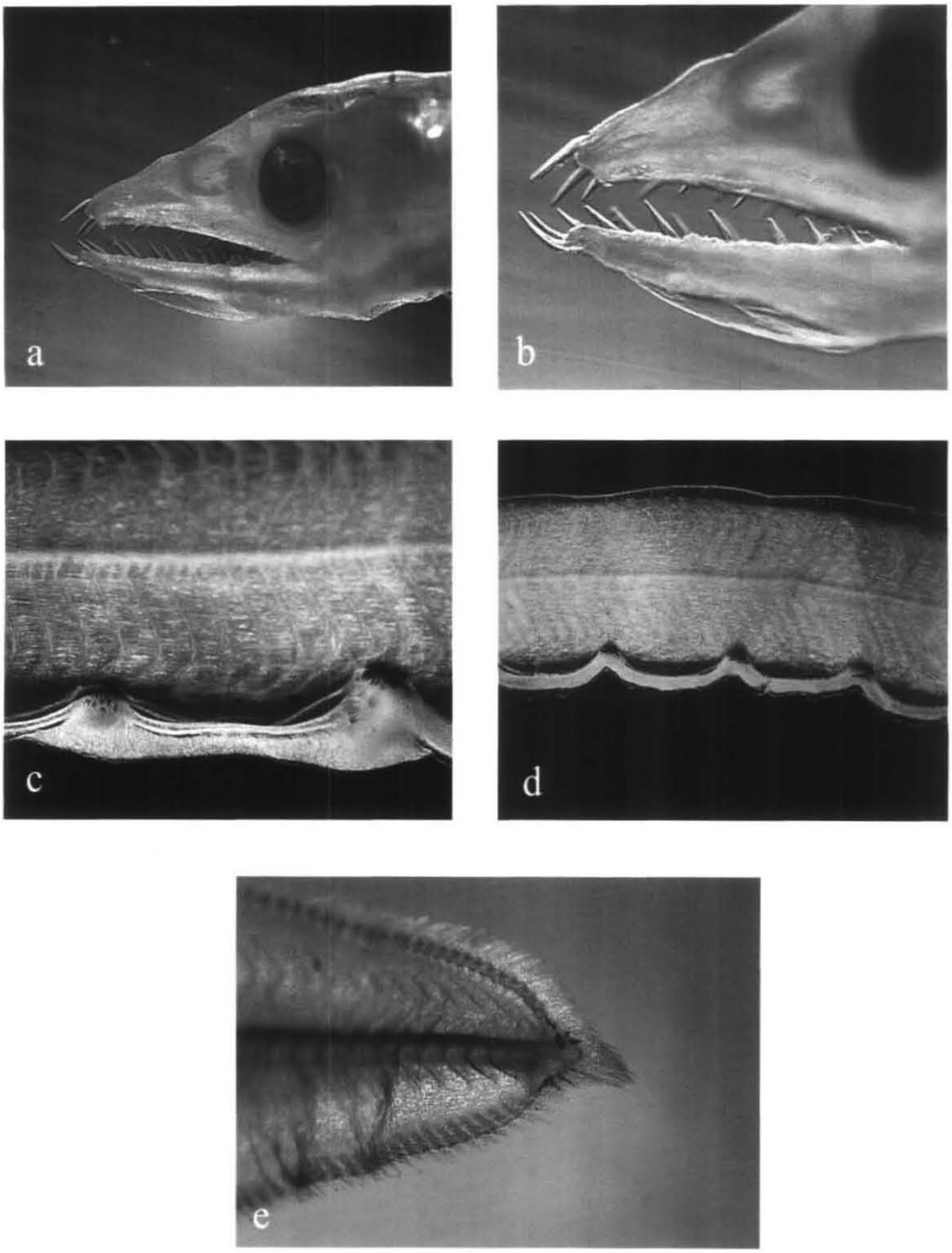


PLATE 10. Ophichthidae-Type B
a. Head b. Teeth c. Liver d. Intestine e. Tail

thickenings; dorsal and anal fins devoid of any pigments.

Type C

Specimens examined = 2; total length = 42-48mm; maximum body height (excluding vertical fins) = 3mm; length of head = 4mm; length of snout = 1.7mm; diameter of eye = 0.58; position of nasal pit = 1.1mm; total myomeres = 146-149; pre anal myomeres = 83mm; post anal myomeres = 66; origin of dorsal fin = 79^{th} myomere; teeth = I+I+3+6 / I+6+2.

Body more or less of uniform height, posteriorly ending in a blunt tail; head moderately elongate (Plate11. a); snout conical; upper and lower jaws of the same length; nasal region well developed with nostrils not distinct; cleft of mouth oblique, curved, reaching up to the middle of the eye; eye circular; upper and lower jaws provided with sharp teeth on its each half (Plate11. b): in the upper jaw a single, large antero-dorsal tooth followed by a large tooth three comparatively smaller teeth than the preceding ones and in the posterior are six very small teeth; in the lower jaw a single large tooth in the tip followed by six large teeth and two small teeth; branchiostegals not clear; pectoral fin long with indistinct rays; dorsal and anal fin ends abruptly near the caudal fin, with very feeble rays; caudal fin absent; hypurals well developed and freely protrudes out (Plate11. f); intestine more than ½ the total length, looped or festooned with nine prominent humps or thickenings at the junction between adjacent loops and eight less prominent thickenings in the middle of each loop; liver with two connected lobes (Plate11. e).

The larva is very conspicuously pigmented with a very vague pigment patch on the tip of upper jaw; single pigment spot on the middle of the margin of upper jaw; patch of pigment on the tip of lower jaw; another pigment patch near the hind brain; cluster of pigment spots near the base of pectoral fin; dorsal and anal fin ray bases with out any pigmentation; cluster pigments near the caudal region; lateral pigmentation in the form of twenty widely placed internal pigment patches on the mid line (Plate11. c), starting from 10^{th} myosepta onwards; streaks of pigment just

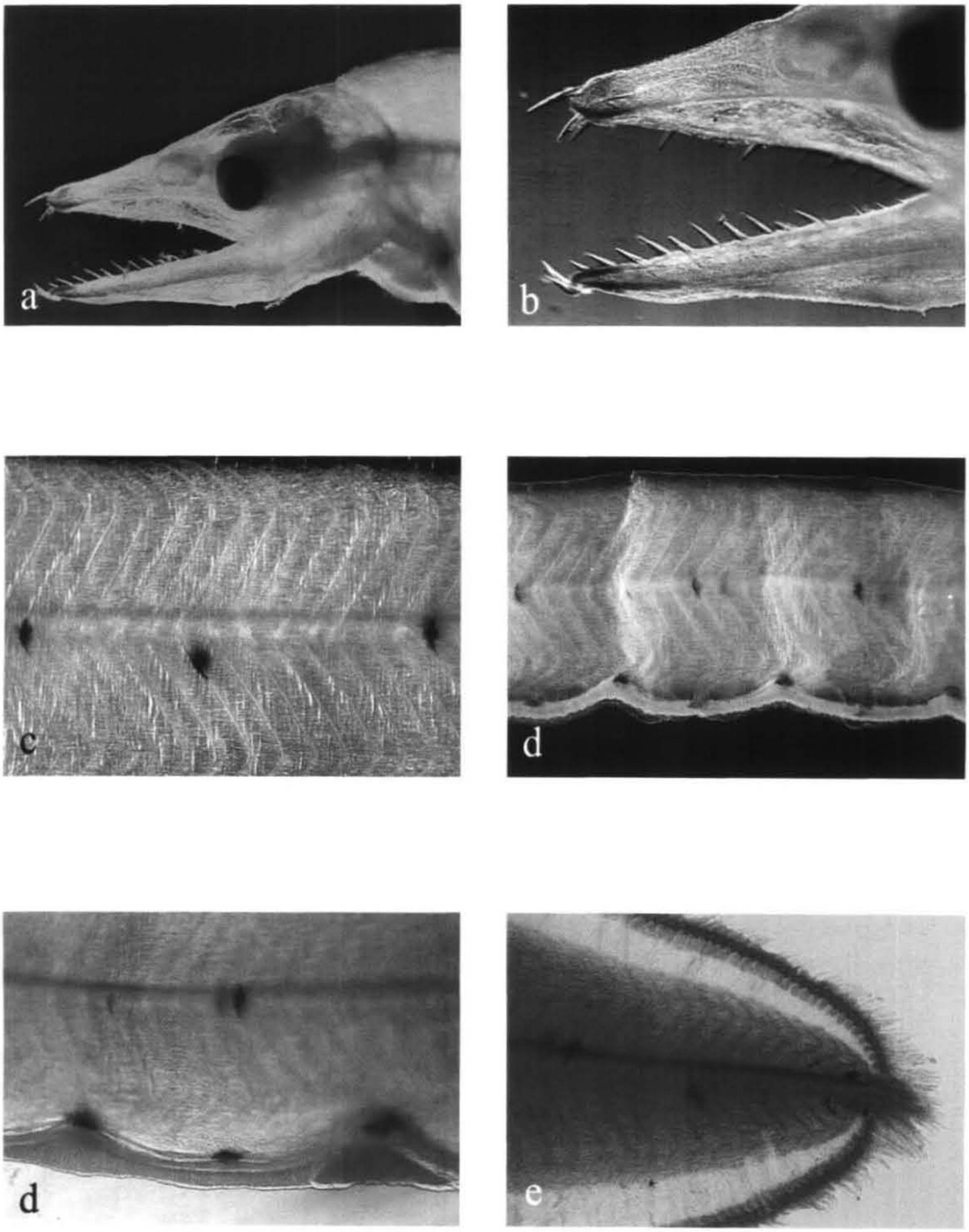


PLATE 11. Ophichthidae-Type C
a. Head b. Teeth c. Lateral pigmentation
d. Intestine e. Liver f. Tail

below the mid lateral line starting from 14^{th} myosepta; nine widely placed clusters of branching chromatophores in the post anal region just above the anal fin; branched, closely packed group of chromatophores on all the thickenings of the intestine (Plate11. d).

Type D

Specimens examined = 1; total length = 90mm; maximum body height (excluding vertical fins) = 6mm; length of head = 6mm; length of snout 2.01mm; diameter of eye = 0.8mm; position of nasal pit = 1.28mm; total myomeres = 142mm; pre anal myomeres = 76; post anal myomeres = 66; origin of dorsal fin = 72^{nd} myomere; dorsal fin rays = 210; anal fin rays = 200; teeth = I+I+4+6 / I+7+3.

Body moderately elongate, compressed, tapering posteriorly to a slightly round tail; head moderately elongate (Plate12. a); snout conical; upper jaw longer than lower jaw; nasal organ developed, with anterior nostrils not yet separated; cleft of mouth oblique, curved, reaching to the middle of the eye; eye round; well developed acute teeth on each half of both the jaws (Plate12. b): in upper jaw an antero-dorsal tooth followed by a single large fang like tooth; four large teeth and a series of six small teeth; in lower jaw a single large tooth anteriorly, followed by seven large teeth and a set of three small teeth; branchiostegals developed (more than 16); pectoral fin round with indistinct rays; dorsal and anal fins well developed with distinct rays; caudal fin present with three distinct rays (Plate12. f); hypurals present; intestine looped (Plate12. d), more than ½ the total length with nine thickenings between adjacent loops; liver with two connected lobes.

Larval pigmentation is very prominent and described as follows: three pigment spots on the margin of upper jaw; cluster of pigment spots near the base of pectoral fin; no pigmentation on anal and dorsal fin ray bases; lateral pigmentation in three groups: first group consists of nine widely placed clusters of pigment spots in the pre anal region (Plate12. e) along the mid line starting from 8^{th} myosepta; second group of six internal pigment patches just below the mid line in the post anal region

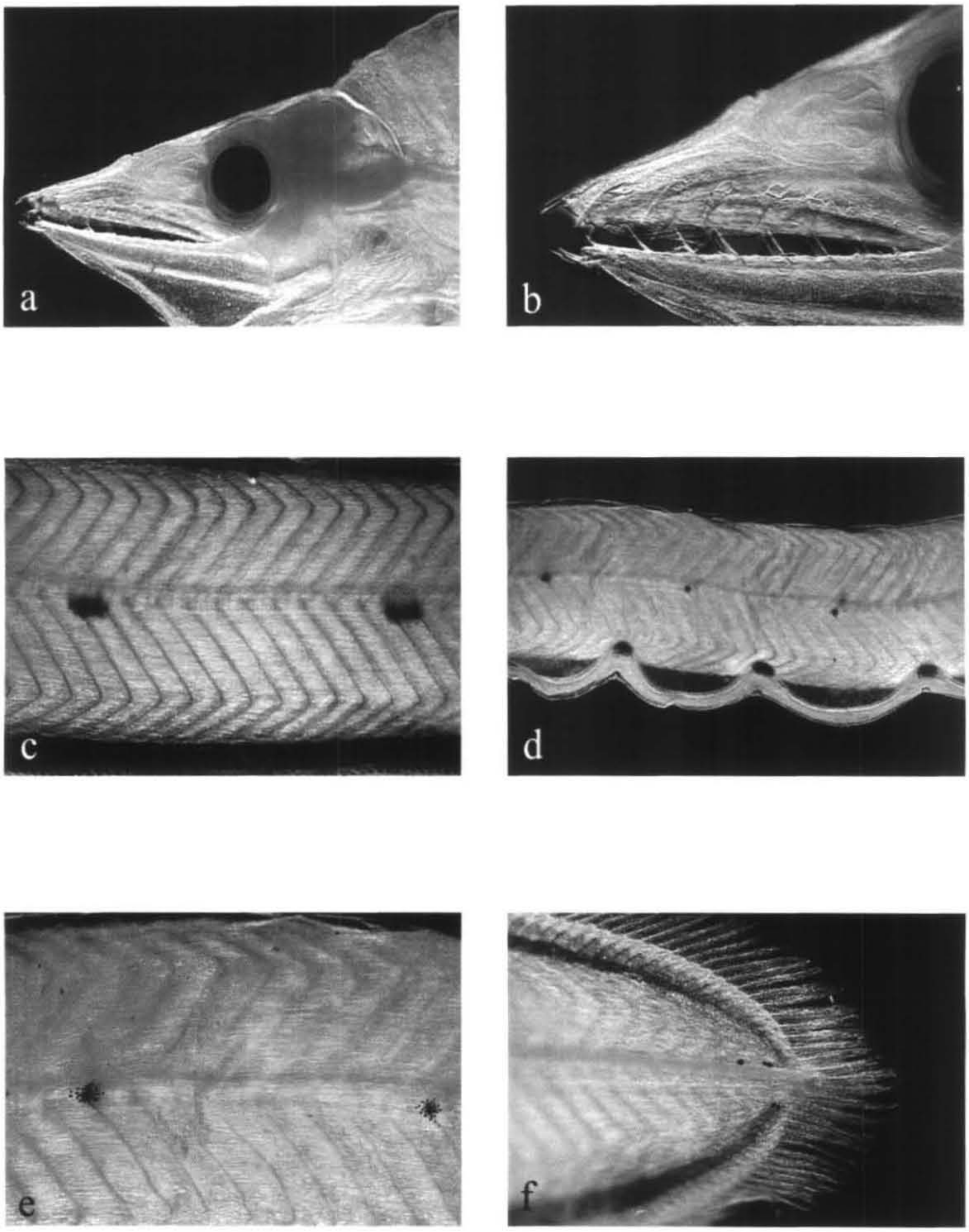


PLATE 12. Ophichthidae-Type D
a. Head b. Teeth c. Lateral pigmentation (post anal) d. Intestine e. Lateral pigmentation (pre anal) f. Tail

(Plate12. c), from the 78^{th} myomere onwards; third group consists of row of closely placed pigment spots along the myosepta just below the mid line, appearing as streaks and are mostly present in the region where the internal pigments are; five widely placed clusters of pigment spots above the anal fin; closely packed, branched chromatophores above the nine humps or thickenings of the intestine; four pigment spots near the caudal region.

Type E

Specimens examined = 19; total length = 41-62mm; maximum body height (excluding vertical fins) = 4mm; length of head = 4mm; length of snout = 1.34mm; diameter of eye = 0.74mm; position of nasal pit = 0.77mm; total myomeres =126-131; pre anal myomeres = 41; post anal myomeres = 86; origin of dorsal fin = 21^{st} myomere; dorsal fin rays = 164; anal fin rays = 209; caudal fin rays = 4+3, teeth = I+6+3 / I+7.

Body transparent, broad, leaf like, sharply tapering towards both the ends, posteriorly in a bluntly pointed tail and anteriorly in an elongate head (Plate13. a); snout sharply conical; lower jaw slightly bigger than the upper jaw; nasal pit well developed with the nostrils not distinct; cleft of mouth straight, slightly curved, reaching to the middle of the eye; eye circular; sharply pointed and forwardly directed teeth present on both jaws (Plate13. b): each half of the upper jaw is provided with a clasper like tooth in the front, followed by six large teeth and three small teeth; lower jaw on its each half have almost horizontally placed, curved tooth in the anterior most part and seven teeth gradually decreasing in size posteriorly; pectoral fin well developed and oval in shape, rays not distinct; well developed and distinct rays on both dorsal and anal fins; caudal fin with well developed hypurals and seven distinct rays (Plate13. e); intestine short, less than half the body length, not looped but with four distinct thickenings (Plate13. c); liver with two separate lobes (Plate13. d).

A row of six pigment spots on the anterior part of upper jaw; three pigment spots near the tip of the lower jaw; four branched chromatophores near the region of

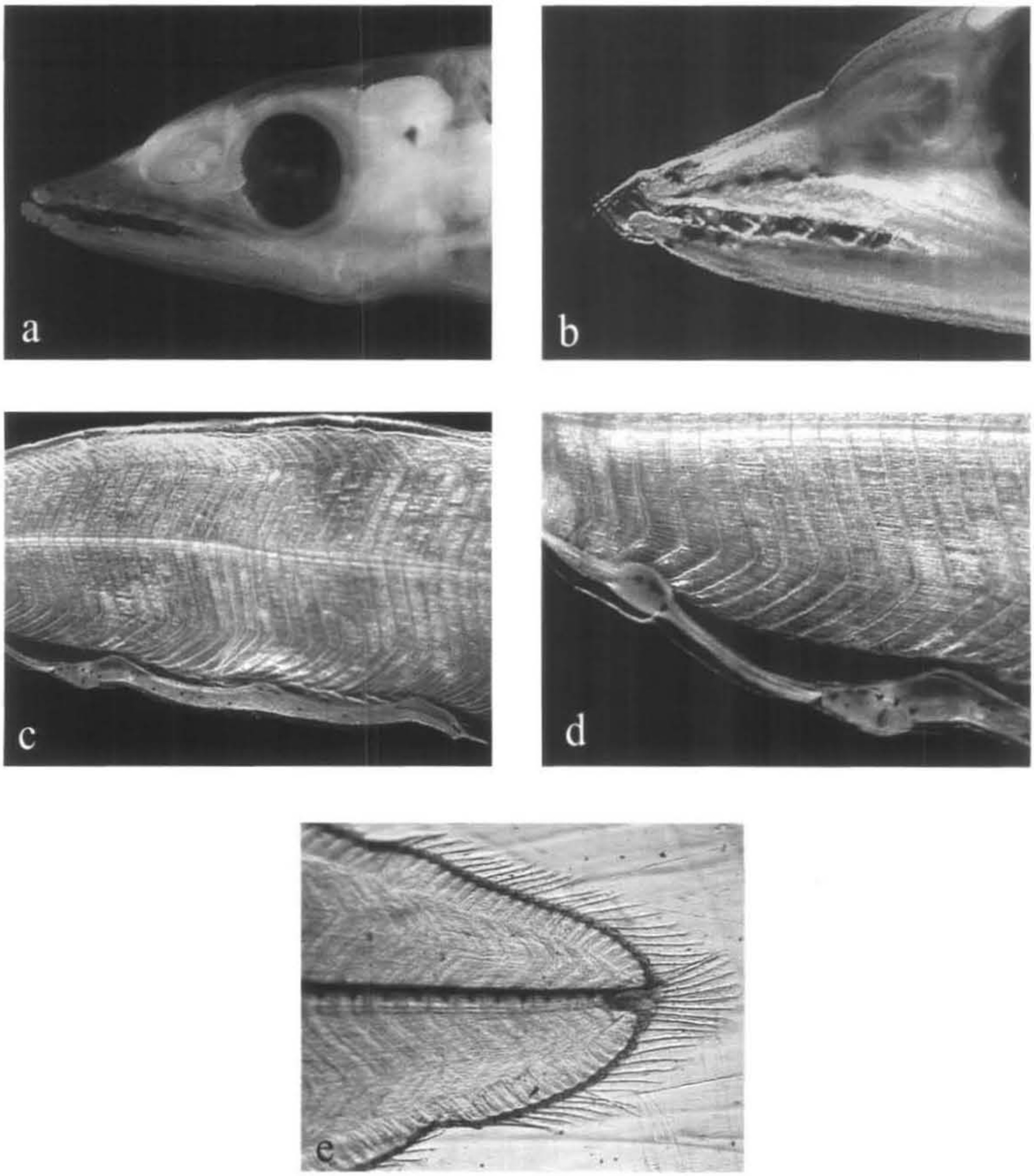


PLATE 13. Ophichthidae-Type E
a. Head b. Teeth c. Intestine d. Liver
e. Tail

hind brain; four less conspicuous, internal chromatophores ahead of the heart; two chromatophores near the base of pectoral fin; stellate, branched chromatophores present above the thickenings and also scattered on the lateral and ventral side along the length of intestine.

Except for the pigmentation described above the rest of the body of the larva was without any pigmentation.

Type F

Specimens examined = 27; total length = 38-63mm; maximum body height (excluding vertical fins) = 5mm; length of head = 4mm; length of snout = 1.22mm; diameter of eye = 0.54mm; position of nasal pit = 0.77mm; total myomeres = 123-156; pre anal myomeres = 64; post anal myomeres = 84; origin of dorsal fin = 63rd myomere; dorsal fin rays = 257; anal fin rays = 184; caudal fin rays = 3+2; teeth = I+6+4 / I+6+2

Body elongate, shallow, gradually tapering posteriorly to a moderately round tail and anteriorly to a highly elongate head (Plate14. a); snout conical and pointed; lower jaw longer than upper jaw; nasal organ developed; a constriction near the nasal organ; cleft of mouth straight, slightly curved reaching to the middle of the eye; eye circular; dentition very prominent in both the jaws (Plate14. b), each half of the upper and lower jaws is provided with a clasper like, almost horizontally placed tooth in the tip; in the upper jaw six large teeth which slightly decrease in size posteriorly, are arranged behind the anterior most tooth followed by four small teeth; in addition to the anterior most tooth, lower jaw has six large teeth and two small teeth; pectoral fin oval; dorsal and anal fin well developed with distinct rays; caudal fin with five distinct rays (Plate14. d); hypurals well developed; liver with two separate lobes (Plate14. c); intestine more or less ½ the total length with three prominent thickenings, the third thickening associated with the kidney; three less conspicuous thickenings between the second and the third thickening.

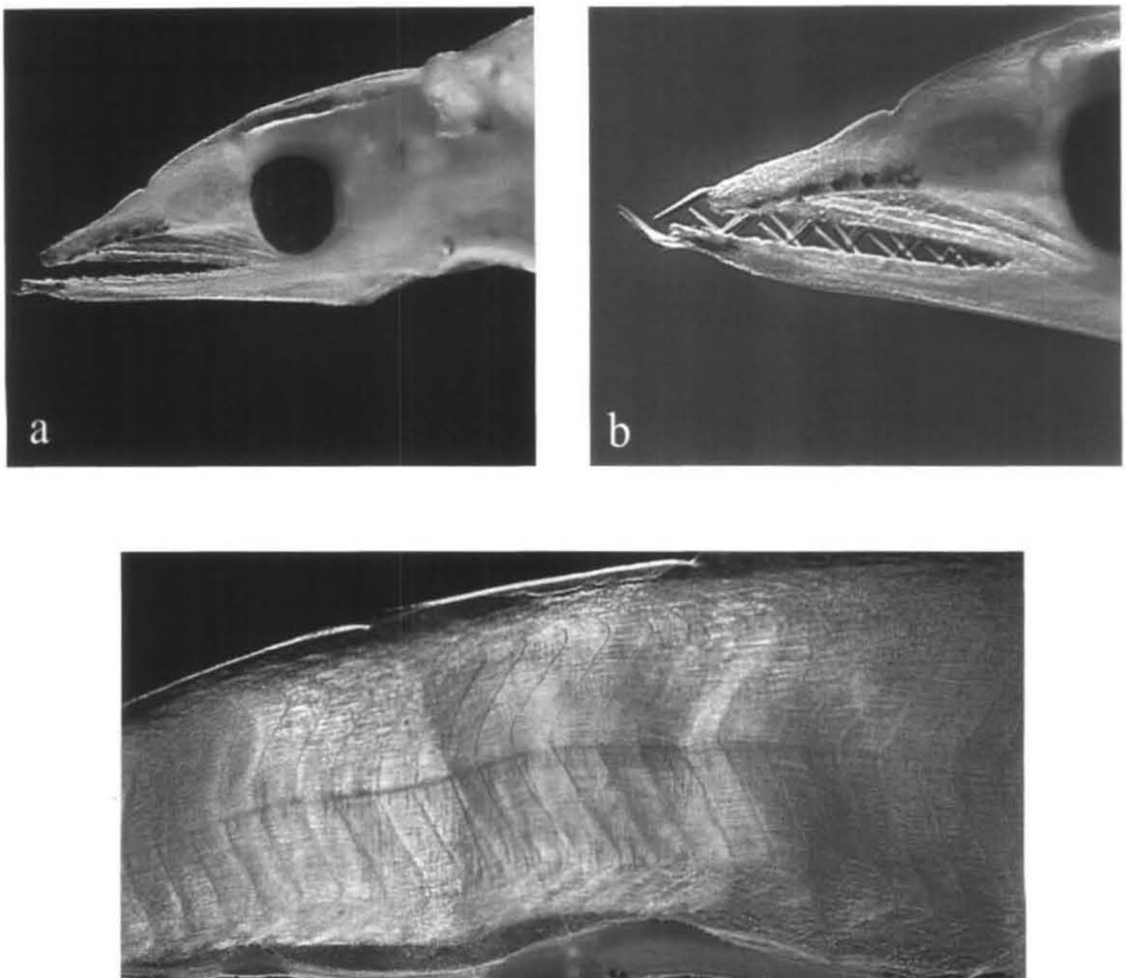


PLATE 14. Ophichthidae-Type F
a. Head b. Teeth c. Liver d. Tail

Pigmentation in the larva is conspicuous as described here: a row of chromatophores on the upper jaw extending towards the nasal organ; single patch of pigment near the tip of lower jaw; two large, stellate, branched chromatophores near the hind brain region; single pigment patch near the base of pectoral fin; a few chromatophores on the bases of posterior most dorsal fin rays; majority of the anal fin rays with pigments on its base; no lateral pigmentation; intestinal pigmentation as follows: two stellate, branched chromatophores on the ventral side of the gut anterior to the first swelling; single, branched chromatophore on the ventral side between the first and second thickenings; a few branched chromatophores below the gastric region; first thickening with branched, stellate, chromatophores on the dorsal side and in the rest of the thickenings these are between the intestine and the overlying kidney.

Family - Muraenidae

This is one of the most homogenous and one of the important of the eel families. It does not show the great variations in larval and adult morphology characteristics of the other two large eel families viz., Ophichthidae and Congridae. Muraenid larvae can be charaterised as "small to moderate sized leptocephali; body moderately deep; tail broadly rounded; gut a simple, narrow tube with out loops or thickenings, about one half to three- fourths standard length; dorsal fin variable, originating any where from shortly behind head to near tip of tail; head with short blunt snout; posterior nostril near level of upper margin of eye; pectoral fin greatly reduced, seldom more than a minute, fleshy flap but is more usually absent; pigmentation variable, may consist of small melanophores along gut, on head, dorsal midline, base of fin rays or sub cutaneously on under side of spinal cord, but never on lateral body surface; maximum size generally less than 100mm".

The greatly reduced pectoral fin is unique to muraenid larvae. Other eels have lost the pectoral fin in the adult, but only the morays shows this reduction in the larval stage. The high posterior nostril, the short, blunt snout and the broadly rounded tail further characteise the muraenid larvae.

Anarchias sp.

Specimens examined = 2; total length = 43-44mm; maximum height (excluding vertical fins) = 7mm; length of head = 3mm; length of snout = 0.9mm; diameter of eye = 0.58mm; position of nasal pit = 0.29mm; position of first nostril = 0.29mm; size of first nostril = 0.1mm; position of second nostril = 0.78mm; size of second nostril = 0.07mm; total myomeres = 103-109; pre anal myomeres = 57; post anal myomeres = 52; origin of dorsal fin = 100th myomere; dorsal fin rays = 34; origin of anal fin = 103rd myomere; anal fin rays = 23; caudal fin rays = 2+2; teeth = I+I+3+4 / I+5+2.

Spindle shaped, elongate body with rounded tips; head small with a convex dorsal profile (Plate15. a); snout short and round; eye sub circular; cleft of mouth oblique, straight, reaching beyond the center of eye; nostrils well developed; each half of upper jaw with a short, slender grasping tooth, a large, curved, pointed fang like tooth followed by three large teeth and four small teeth; lower jaw on its each half bears a single, curved, almost horizontally placed tooth in its tip followed by five long, slender teeth and two small teeth; pectoral fin a minute, rudimentary, fleshy flap, barely distinguishable; dorsal and anal fin restricted to the posterior, with dorsal fin originating slightly ahead of anal fin; both dorsal and anal fins with well developed rays; caudal fin supported by four rays with the hypurals difficult to distinguish (Plate15. b); anal opening at 57th myomere.

The leptocephalus is devoid of pigmentation on the body, fins or intestine, which is a characteristic feature.

Gymnothorax sp.

Specimens examined = 1; total length = 58mm; maximum body height (excluding vertical fins) = 8mm; length of head = 3mm; length of snout = 0.91mm; diameter of eye = 1.34mm; position of nasal pit = 0.45mm; position of first nostril = 0.39mm; size of first nostril = 0.11mm; position of second nostril = 0.91mm; size of second nostril =

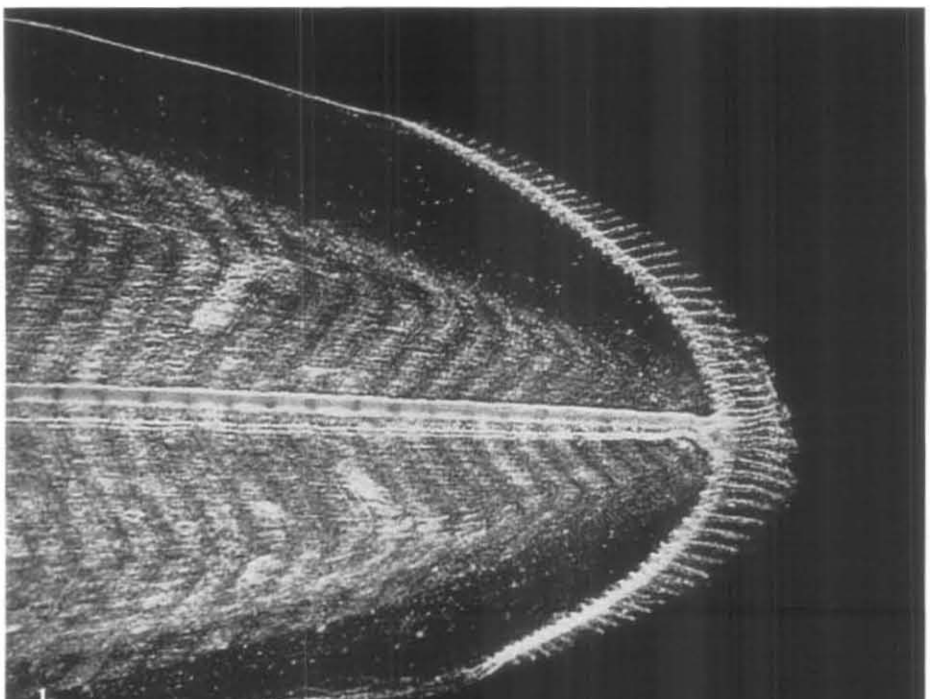


PLATE 15. Muraenidae- *Anarchias* sp.
a. Head b. Tail

0.18mm; total myomeres = 138; pre anal myomeres = 89; post anal myomeres = 49; origin of dorsal fin = 44^{th} myomere; dorsal fin rays = 200; anal fin rays = 30; caudal fin rays = 4; teeth = I+5+5 / I+10.

Moderately elongate, spindle shaped body with broadly rounded ends; head small with a convex dorsal profile (Plate16. a); snout short, bluntly pointed; nasal organ with well differentiated nostrils, posterior nostril slightly above the upper margin of eye; eye circular; cleft of mouth slightly oblique, curved reaching beyond the centre of the eye; upper jaw marginally longer than lower jaw; teeth in the half of upper jaw consisting of three groups (Plate16. b): an anterior, slender, long, acute grasping tooth, a second series of five large teeth followed by five comparatively smaller teeth; dentition in lower jaw in two groups: an upwardly curved, sharp tooth originating from just below the tip followed by a series of ten teeth, decreasing in size posteriorly; six branchiostegal rays discernible (in the specimen examined) curving up over the opercular region; pectoral fin very small, barely distinguishable with rudiment rays; dorsal developed, originating well ahead of the anal opening with distinguishable rays; caudal fin round with four rays (Plate16. f); hypurals indistinct; anal fin with distinguishable rays; dorsal and ventral diaphanous zones becoming broader towards the posterior region; alimentary canal straight, accounting to $3/4^{th}$ length of the body.

A subcutaneous row of chromatophores on the anterior margin of upper jaw; a same pattern on the ventral side of the posterior part of lower jaw; scattered minute pigment spots on the dorsal side of head, above the brain (Plate16. c); a few subcutaneous chromatophores behind the eye; 6-7 chromatophores above heart; five very small pigment spots on the base of pectoral fin; a group of stellate chromatophores ventral to the heart (Plate16. d), this continuing as a row on the ventral side of the intestine up to the anal opening; a second row of chromatophores on the dorsal side of the intestine posterior to the gastric region (Plate16. e) and continuing to the anal opening; a mid dorsal row of pigment spots originating from the 9^{th} myomere to the origin of dorsal fin; a row of internal melanophores on the

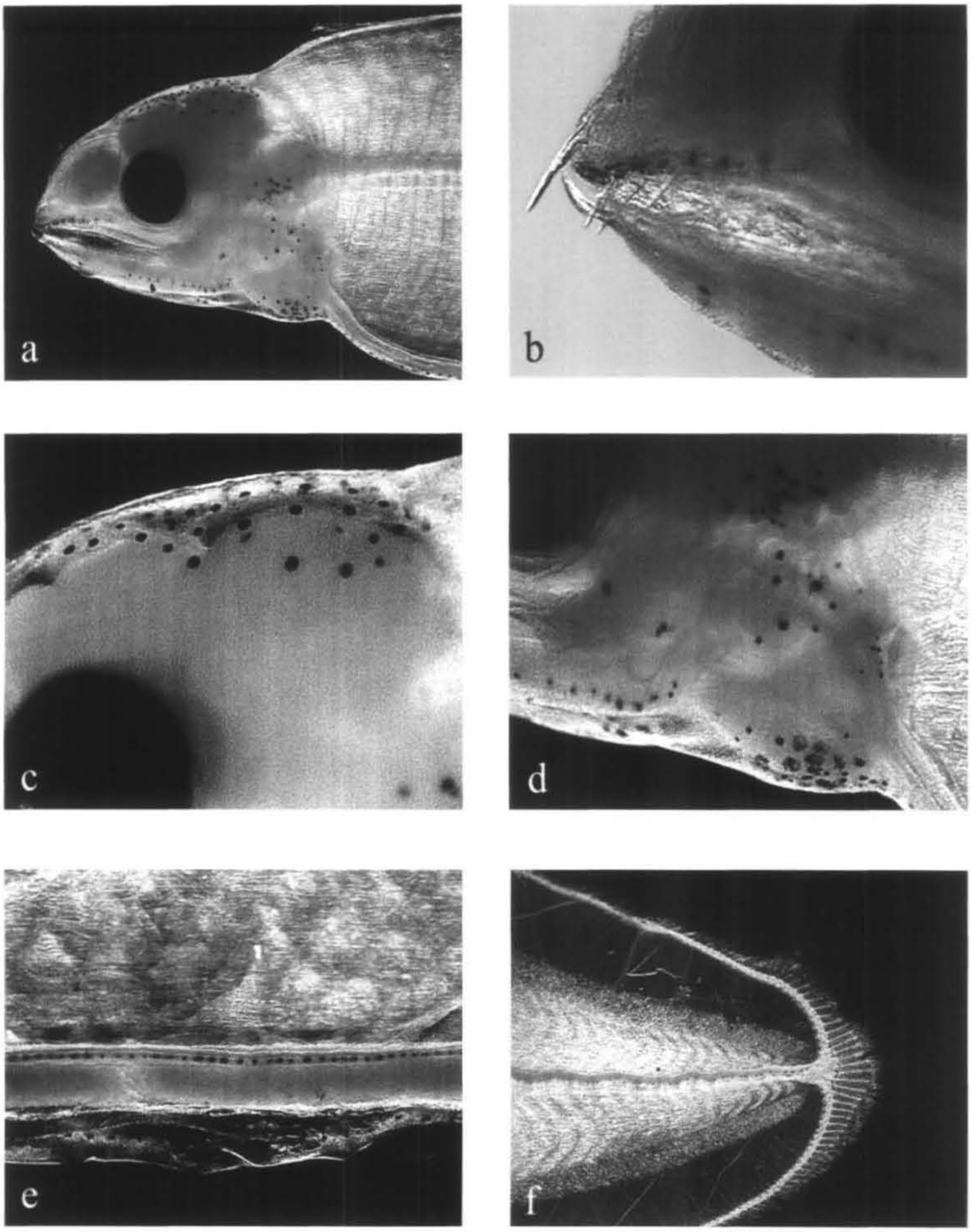


PLATE 16. Muraenidae- *Gymnothorax* sp.
a. Head b. Teeth c. Pigmentation on dorsal side of head d. Pigmentation on heart e.Pigmentation on dorsal side of intestine f. Tail

midline from head to tail; pigmentation on the base of posterior most dorsal and anal fin rays; all caudal fin rays with pigments on its base.

Uropterygius sp.

Specimens examined = 1; total length = 57mm; maximum height (excluding vertical fins) = 8mm; length of head = 3mm; length of snout = 1.09mm; diameter of eye = 0.64mm; position of nasal pit = 0.36mm; position of first nostril = 0.42mm; size of first nostril = 0.07mm; position of second nostril = 0.91mm; size of second nostril = 0.14mm; total myomeres = 118; pre anal myomeres = 106; post anal myomeres = 12; origin of dorsal fin = 108th myomere; dorsal fin rays = 40; origin of anal fin = 111th myomere; anal fin rays = 19; caudal fin rays = 2+2; teeth = I+4+5 / I+7+2.

Moderately elongate leptocephali with a blunt pointed snout (Plate17. a) and a broadly rounded tail (Plate17. f); cleft of mouth oblique, curved, extending very much beyond the centre of eye; eye circular; nasal organ with well differentiated nostrils, posterior nostril placed slightly above the upper margin of eye; sharp, pointed dentition on each half of both jaws (Plate17. b): upper jaw has a slender, long, pointed tooth in the tip; four large teeth slightly decreasing in size follows of which the first tooth is curved and five small teeth in the posterior part; lower jaw bears a slender, upwardly curved tooth in the tip followed by seven equally sized large teeth and two slender comparatively small teeth; pectoral fin rudimentary (Plate17. d); dorsal and anal fins restricted to the posterior with the dorsal origin slightly ahead of the anal origin, both fins with discernible rays; caudal fin with indistinct hypurals and four distinct rays; alimentary canal a long, straight tube; anal opening at 106th myomere.

Two pigment spots near the anterior margin of upper jaw; a cluster of pigment on the dorsal side of head; a few subcutaneous spots behind the eye (Plate17. c); a row of six pigment spots outlining the origin of gut near the base of pectoral fin (Plate17. c); widely placed pigment spots on the ventral side of the

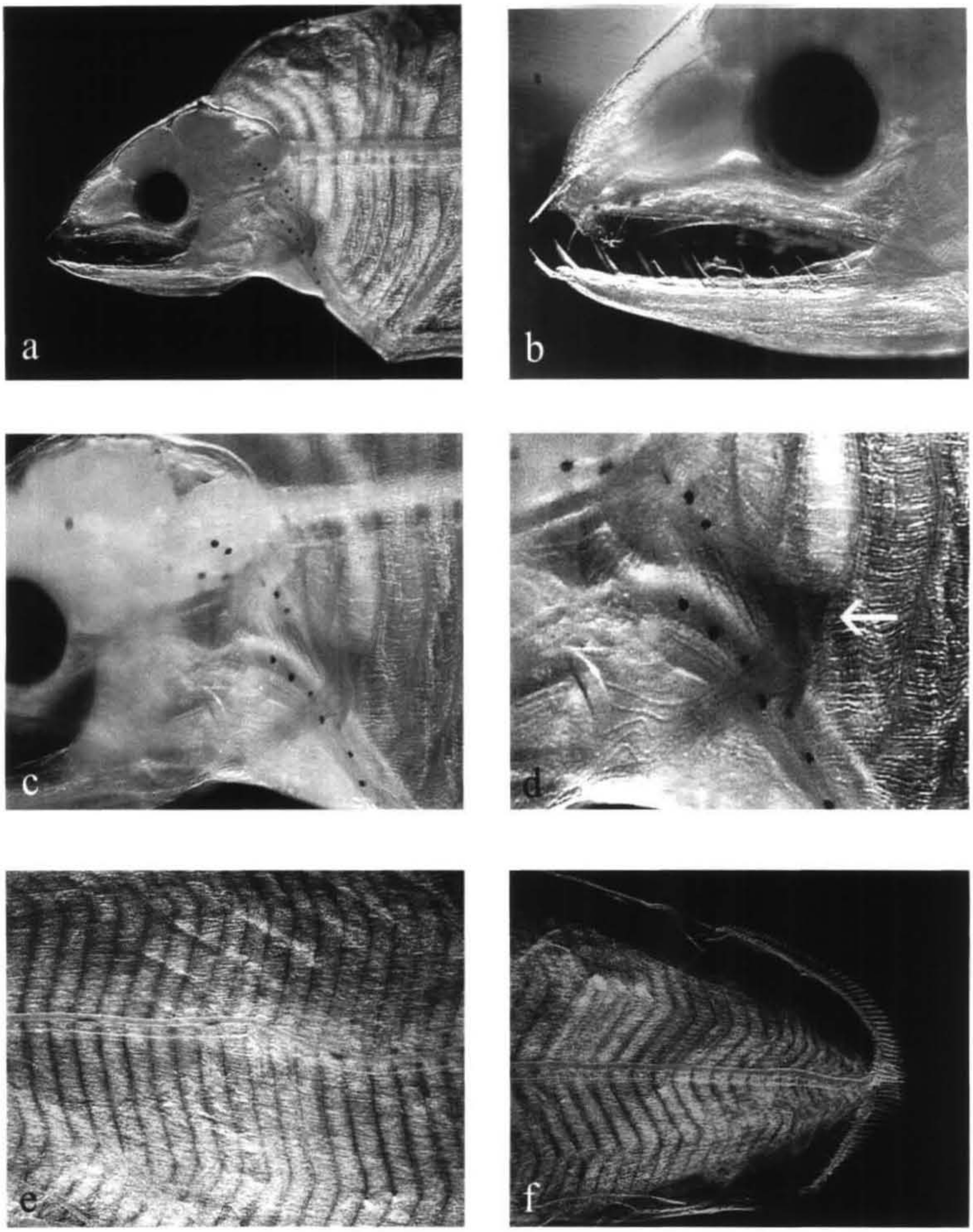


PLATE 17. Muraenidae- *Uropterygius* sp.
a. Head b. Teeth c. Pigmentation in the head region d. Pectoral fin e. Lateral pigmentation f. Tail

intestine, starting just ahead of the gastric region and continuing to the anal opening; lateral pigmentation in the form of 18 widely placed small internal patches on the mid line (Plate17. e); majority of the dorsal and anal fin rays with pigmentation; no pigments on caudal fin rays; single row of pigment spots on the mid ventral side lining the area between anal opening and anal fin origin.

Type A

Specimens examined = 2; total length = 41-53mm; maximum height (excluding vertical fins) = 8mm; length of head = 3mm; length of snout = 0.93mm; diameter of eye = 0.77mm; position of nasal pit = 0.25mm; position of first nostril = 0.25mm; size of first nostril = 0.14mm; position of second nostril = 0.85mm; size of second nostril = 0.14mm; total myomeres =118-120; pre anal myomeres = 75; post anal myomeres = 43; origin of dorsal fin = 31st myomere; dorsal fin rays = 310; anal fin rays = 190; caudal fin rays = 2+1; teeth = I+5+9 / I+7+4.

Elongate, broad body with rounded tips; head with convex dorsal profile (Plate18. a); snout, short, blunt and round; cleft of mouth oblique, slightly curved, reaching beyond the middle of eye; eye circular; anterior and posterior nostrils separate with the posterior nostril placed well above the upper margin of the eye; branchiostegal rays discernible (approx. 11) curving upwards over the opercular region; each half of upper jaw with an anterior clasping tooth followed by five large teeth decreasing in size posteriorly and nine small teeth; lower jaw bears single clasping tooth in its tip, seven long, slender, pointed teeth with a slight decrease in length posteriorly followed by four comparatively small teeth in its each half; a row of four distinct pores on the ventral side of lower jaw; upper jaw longer than lower jaw; pectoral fin very small with rudimentary rays; dorsal fin well developed with distinct rays, originating well ahead of anal fin; anal fin with distinct rays; caudal fin with three rays on the hypurals (Plate18. c); intestine straight with out any swellings; dorsal and ventral diaphanous zones becoming broader after the post anal region.

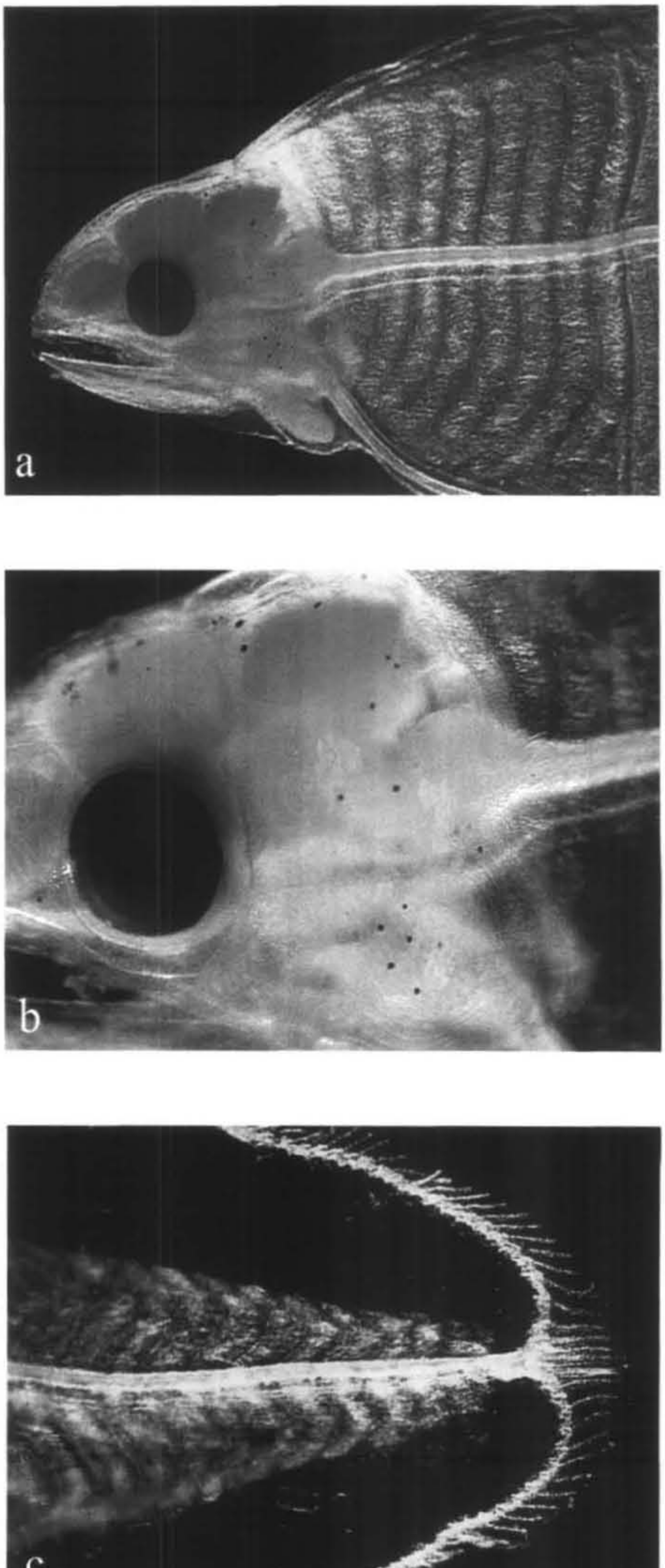


PLATE 18. Muraenidae- Type A
a. Head b. Pigmentation on head
c. Tail

A few pigment spots near the tip of upper jaw; scattered melanin pigment spots on the region of hind brain, behind eye and above the gill region (Plate18. b). Apart from this, the rest of the larva was with out any pigmentation.

Type B

Specimens examined = 1; total length = 62mm; maximum height (excluding vertical fins) =8mm; length of head = 4mm; length of snout = 1.06mm; diameter of eye = 0.9mm; position of nasal pit = 0.26mm; position of first nostril = 0.26mm; size of first nostril = 0.16mm; position of second nostril = 1.25mm; size of second nostril = 0.13mm; total myomeres = 135; pre anal myomeres = 79; post anal myomeres = 56; origin of dorsal fin 36^{th} myomere; dorsal fin rays = 200; anal fin rays = 42; caudal fin rays = 3+2; teeth = I+4+7 / I+11.

Body elongate, spindle shaped with a bluntly pointed head (Plate19. a) and moderately round caudal fin (Plate19. e); blunt snout; cleft of mouth oblique, curved, reaching just beyond the centre of eye; posterior nostril very much above the upper margin of eye; circular eye; branchiostegals developed (more than 11) curving upwards above the opercular region (Plate19. d); upper jaw longer than lower jaw; even though the first clasping tooth is missing from then upper jaw its presence was evident, apart from this each half of the upper jaw bears four slender, acute teeth decreasing in size posteriorly followed by seven smaller teeth; lower jaw in its each half has a grasping tooth in the tip followed by eleven teeth gradually decreasing in size posteriorly (Plate19. c); pectoral fin in the form of a barely distinguishable, fleshy rudiment; opercular opening very much reduced; dorsal and anal fins with distinguishable rays; origin of dorsal ahead of anal; caudal with four distinct rays; intestine a long straight tube.

Melanin pigment spots scattered all over the head (Plate19. b), heart except lower jaw, giving the head a shaded appearance to the naked eye; a few stellate, branched chromatophores present near the anterior nostril, above and behind the eye;

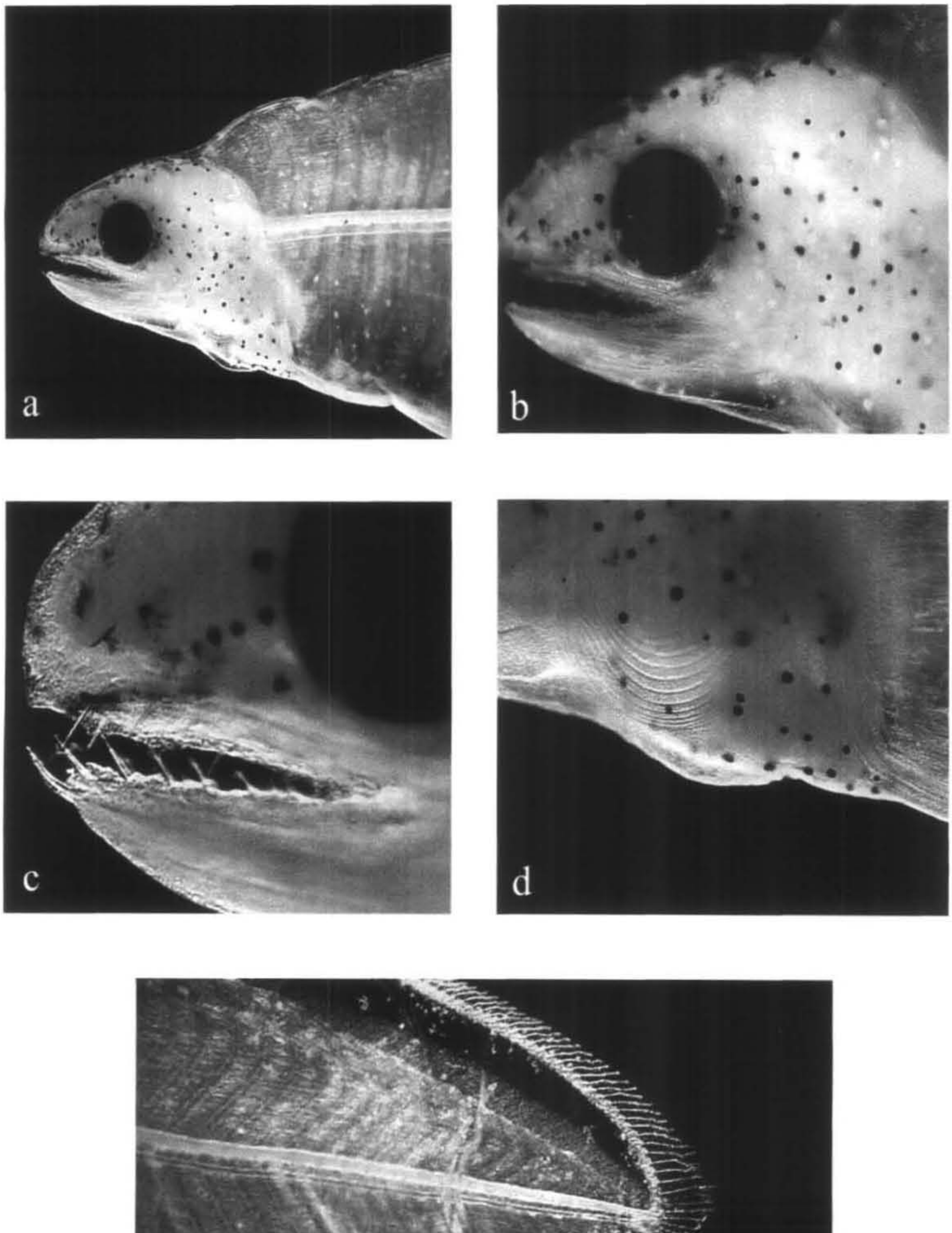


PLATE 19. Muraenidae- Type B
a. Head b. Pigmentation on head c. Teeth
d. Branchiostegal rays e. Tail

pigment spots on a few caudal fin rays and posterior most dorsal fin rays; majority of the anal fin rays with pigmentation; no dorsal, mid lateral or ventral pigmentation.

Type C

Specimens examined = 1; total length = 62mm; maximum height (excluding vertical fins) = 7mm; length of head = 3mm; length of snout = 0.91mm; diameter of eye = 0.7mm; position of nasal pit = 0.32mm; size of first nostril = 0.08mm; position of first nostril = 0.38mm; size of second nostril = 0.15mm; position of second nostril = 0.85mm; total myomeres = 141; pre anal myomeres = 79; post anal myomeres = 62; origin of dorsal fin = 58th myomere; dorsal fin rays = 70; anal fin rays = 80; caudal fin rays = 3+1; teeth = I+4+4 / I+5+4.

Elongate body, tapering slightly towards head (Plate20. a) than tail; tail round; snout bluntly pointed; eye sub circular; cleft of mouth oblique, reaching beyond the centre margin of eye; nostrils separate, posterior nostril placed above the level of eye; upper jaw longer than the lower jaw; branchiostegals discernible (more than 10); a pore (an unidentified structure) between the nostrils on the dorsal margin of nasal pit; dentition (Plate20. b) on each half of the jaws as follows: upper jaw with a long, slender clasping tooth, four large, acute teeth, decreasing in size posteriorly followed by four small teeth; lower jaw bears an acute, upwardly curved tooth in its tip followed by five large teeth, the last being comparatively small than the preceding four and four smaller teeth on the posterior part; very small pectoral fin with rudimentary rays; dorsal and anal fins with distinct rays, dorsal fin originating ahead of the anal fin origin; caudal fin (Plate20. d) with four distinct rays.

Subcutaneous pigment spot on the margin of upper jaw and a few behind the eye; a slightly curved row of pigment spots on the posterior part of lower jaw ahead of heart, a few below the base of pectoral fin; scattered pigment spots on the ventral side of heart, which continues as a single row on the ventral side of gut anterior to the gastric region after which it shifts to the dorsal side of the intestine (Plate20. c) and continues to the anal opening; a mid dorsal row of pigments starting from the ninth

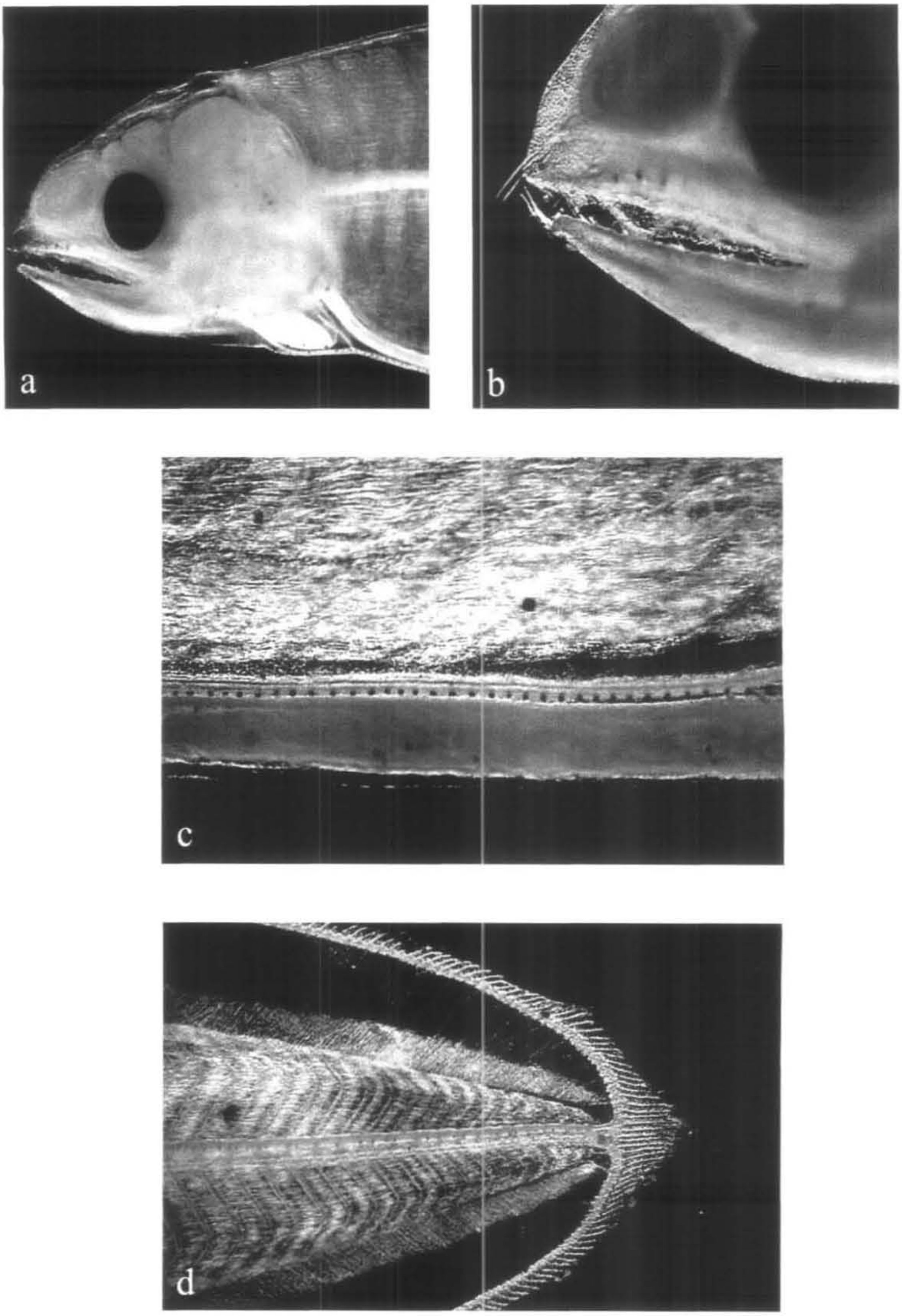


PLATE 20. Muraenidae- Type C
a. Head b. Teeth c. Pigmentation on head
d. Tail

myomere till the origin of dorsal fin; row of mid lateral , sub cutaneous pigment spots from head to tail; majority of dorsal and anal fin rays with pigments on its base; caudal fin rays with no pigmentation.

Family - Nemichthyidae

Nemichthyid leptocephali can be readily distinguished from those of other families by their relatively long and shallow body, depth about one-tenth to one-twentieth. Other characters that distinguish the Nemichthyid leptocephali are: tail moderate or attenuated; gut long and simple with out swellings or loops, anus near end of tail; head with a concave dorsal profile; snout sharp, peg like; dorsal fin short, beginning slightly before level of anus; pectoral fin present; nasal capsule small; small melanophores along top of gut posterior to gastric region, and on bottom of gut anterior to this point; lateral pigment when present, consisting of a few widely spaced spots below mid lateral line; internal melanophores along top of spinal cord extending length of body; maximum size 300-400 mm.

Type A

Specimens examined = 2; total length = 129-130mm; maximum height (excluding vertical fins) = 8mm; length of head = 6mm; length of snout = 2.53mm; diameter of eye = 1.34mm; position of nasal pit = 0.93mm; position of first nostril = 1.06mm; size of first nostril = 0.26mm; position of second nostril = 1.73mm; size of second nostril = 0.45mm; total myomeres = 216-217; pre anal myomeres = 148; post anal myomeres = 69; origin of dorsal fin = 94^{th} myomere; dorsal fin rays = 151; anal fin rays = 60; caudal fin rays = 4+3; teeth = I+I+9+11 / I+12+3

Body elongate; head with a long, sharp snout (Plate21. a); tail moderately attenuated; nasal organ well developed with separate nostrils; eye oval; cleft of mouth straight, oblique reaching not beyond the centre of eye; lower jaw marginally longer than upper jaw; pectoral fin circular with feeble rays; dentition prominent on both jaws (Plate21. b): upper jaw in its each half carries a short antero-dorsal tooth,

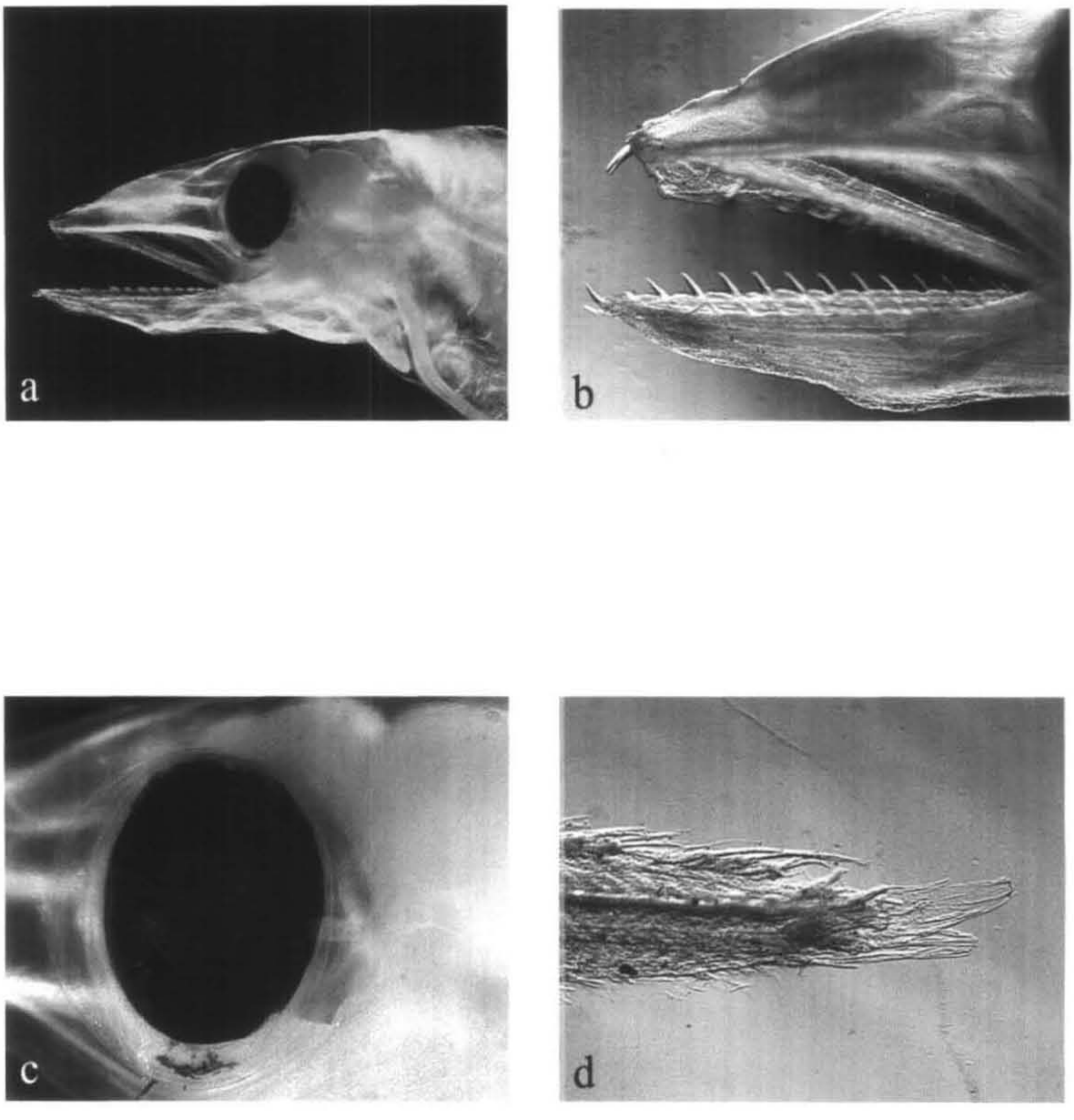


PLATE 21. Nemichthyidae- Type A
a. Head b. Teeth c. Pigmentation on eye
d. Tail

an acute clasping tooth, followed by nine large teeth and eleven small teeth; each half of lower jaw possesses an anterior curved tooth followed by twelve large teeth and three small teeth; dorsal and anal fins with only the posterior most rays well developed, the origin of dorsal fin ahead of the anal fin origin; caudal fin with long, well developed rays; hypurals distinct (Plate21. d); intestine long, with out loops or swellings, accounting to more than 3/4th the length of body.

A group of branched chromatophores below eye (Plate21. c); ventral pigmentation in the form of seven widely spaced, stellate' branched pigment patches of which the first four are present on the dorsal side of the intestine on both sides of body and the last three as a single row only on the ventral side of intestine; fin rays with out pigmentation; rest of the leptocephali with out pigmentation.

Type B

Specimens examined = 1; total length = 79mm; maximum height (excluding vertical fins = 7mm; length of head = 4mm; length of snout = 1.44m; diameter of eye = 0.86mm; position of nasal pit = 0.59mm; size of first nostril = 0.15mm; position of first nostril = 0.66mm; size of second nostril = 0.16mm; position of second nostril = 1.22mm; total myomeres = 194; pre anal myomeres = 105; post anal myomeres = 89; origin of dorsal fin = 57th myomere; dorsal fin rays = 167; anal fin rays = 77; caudal fin rays = 4+3; teeth = I+I+7+14 / I+9+8.

Body moderately elongate; head small (Plate22. a); snout sharp with a concave dorsal profile; tail moderately pointed; nasal organ with well developed and separate nostrils; cleft of mouth oblique and straight, reaching the center of eye; eye oval; pectoral fin oval; dentition (Plate22. b) on each half of upper jaw consists of a short antero-dorsal teeth, a long, clasping tooth followed by seven large teeth and 14 closely packed, short, slender teeth; lower jaw bears a clasping tooth in its tip followed by nine large teeth and eight small teeth in its each half; upper jaw marginally longer than lower jaw; dorsal and anal fins with only the posterior most

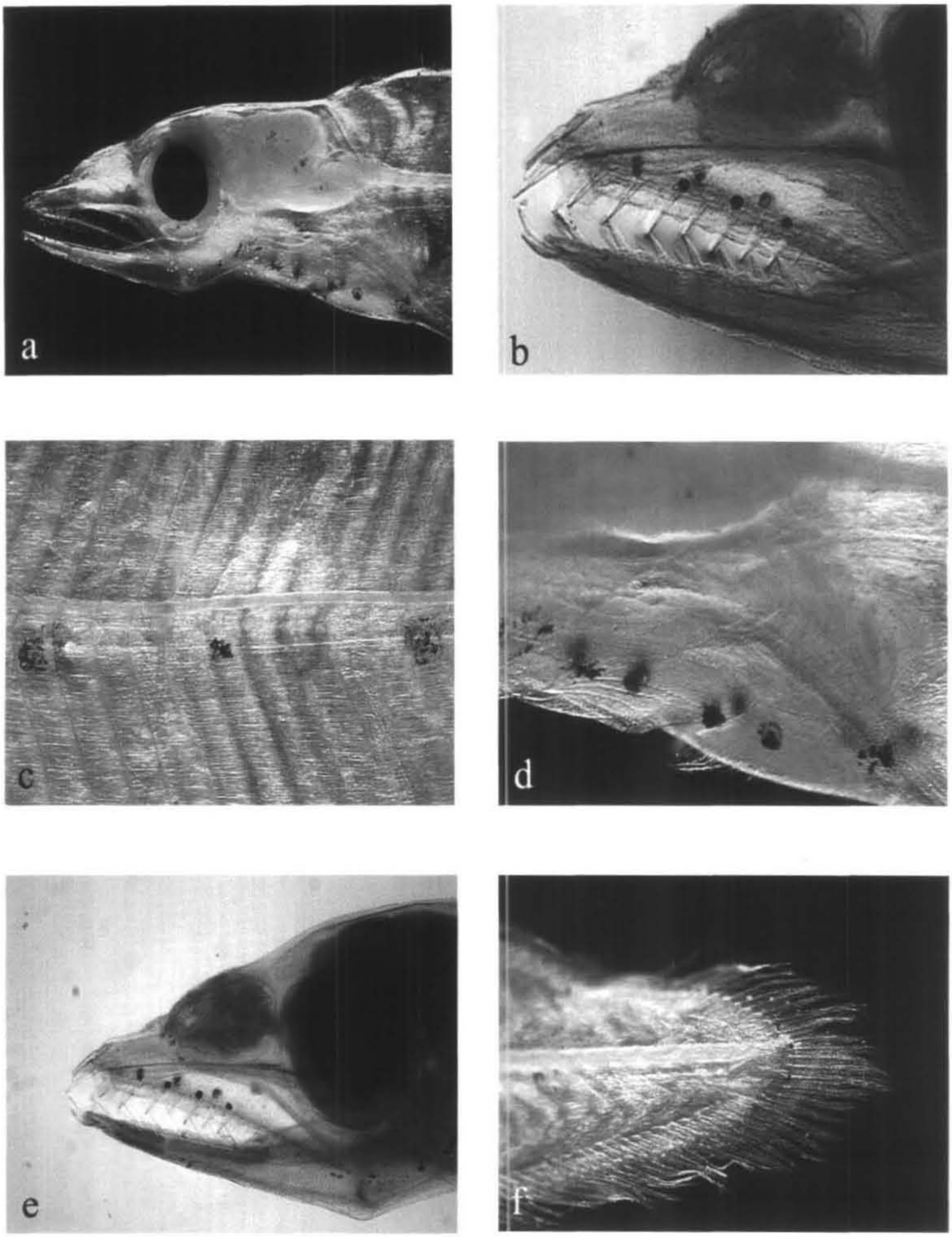


PLATE 22. Nemichthyidae- Type B
a. Head b. Teeth c. Lateral pigmentation
d. Pigmentation on heart region
e. Pigmentation on upper jaw f. Tail

rays discernible; caudal fin with well developed rays (Plate22. f); hypurals distinct; intestine straight with out loops or swellings, accounting for more than ½ the length of body.

The larva was with prominent pigmentation as follows: a row of pigment spots on the margin of upper jaw (Plate22. e); minute pigment spot below eye; two stellate, branched chromatophores on the posterior part of lower jaw ahead of heart; a few stellate chromatophores in and around heart region (Plate22. d); single, stellate, branched chromatophore below the base of pectoral fin; a row of stellate chromatophores on the ventral side of gut continuing till the anal opening; posterior to the gastric region another row of stellate chromatophores on the dorsal side of intestine, most commonly occurring on the right side than the left; 19 widely spaced, large, stellate chromatophores above the anal fin continuing to the tail; a row of 44 stellate, branched chromatophores just below the middle line (Plate22. c) from head to tail; a few posterior most dorsal fin rays with pigmentation; majority of anal and caudal fin rays with pigmentation on its base.

Family - Synaphobranchidae

The leptocephali of the family Synaphobranchidae can easily be identified from its "telescopic eye", which is the main distinguishing character. Other characters are: head variable, rostral filament some times present; gut about one-half to two-thirds standard length, with a series of thickenings; nasal organ closer to snout tip than to eye; ventral pigment a series of rather large melanophores; maximum size usually about 100mm (excluding the rostral filament), up to 200mm.

Type A

Specimens examined = 5; total length = 36-73mm; maximum height (excluding vertical fins) = 7mm; length of head = 5mm; length of snout = 2.46mm; diameter of eye (diameter of the stalked eye ball) = 0.5mm; position of nasal pit = 0.74mm; total myomeres =132-135; pre anal myomeres = 70; post anal myomeres = 64; origin of dorsal fin = 54^{th} myomere; teeth = I+I+? / I+3+6.

Broad, spindle shaped body, tapering to short, pointed tail and moderately elongate, slender head; snout very long, pointed (Plate23. a); cleft of mouth straight not reaching to the centre of the telescopic eye (Plate23. c); pectoral fin long with feeble rays; dorsal and ventral diaphanous zones slightly increasing in breadth after the post anal region; dorsal, anal and caudal fins with feeble, indistinct rays; nasal organ poorly developed; except for the antero-dorsal tooth and clasping tooth in each half of the upper jaw (Plate23. b), rest of the teeth has fallen off in the specimen examined; lower jaw on its each half carries an upwardly curved, slender clasping tooth originating very much below the tip followed by three large teeth and six small teeth; hypurals distinctly developed (Plate23. f); intestine more than half the length of body with six conspicuous and three less conspicuous thickenings (Plate23. e).

Pigment patch on the tip of upper jaw; pigment spot on the tip of lower jaw and also a long streak of pigment on its mid ventral side; single pigment spot on the posterior part of lower jaw and a small streak ahead of it; scattered pigment patches between the nasal organ and eye, below the eye ball and also behind it, on the region of hind brain; branched chromatophores anterior to the heart and below the base of pectoral fin; seven, branched, sub cutaneous chromatophores on the mid lateral line; a cluster of pigment spot near the caudal region; highly branched chromatophore on the ventral side of gut anterior to the gastric region, the same present along the intestine on all the thickenings (Plate23. d) including the one at the anal region; tip of the anus has a highly branched, stellate chromatophore; discontinuous pigmentation on anal fin; dorsal and caudal fins devoid of pigmentation.

Type B

Specimens examined = 1; total length = 37mm; maximum body height (excluding vertical fins) = 5mm; length of head = 5mm; length of snout = 2.46mm; total myomeres = 107; pre anal myomeres = 58; post anal myomeres = 49; teeth = I+I+2+11 / I+6+6.

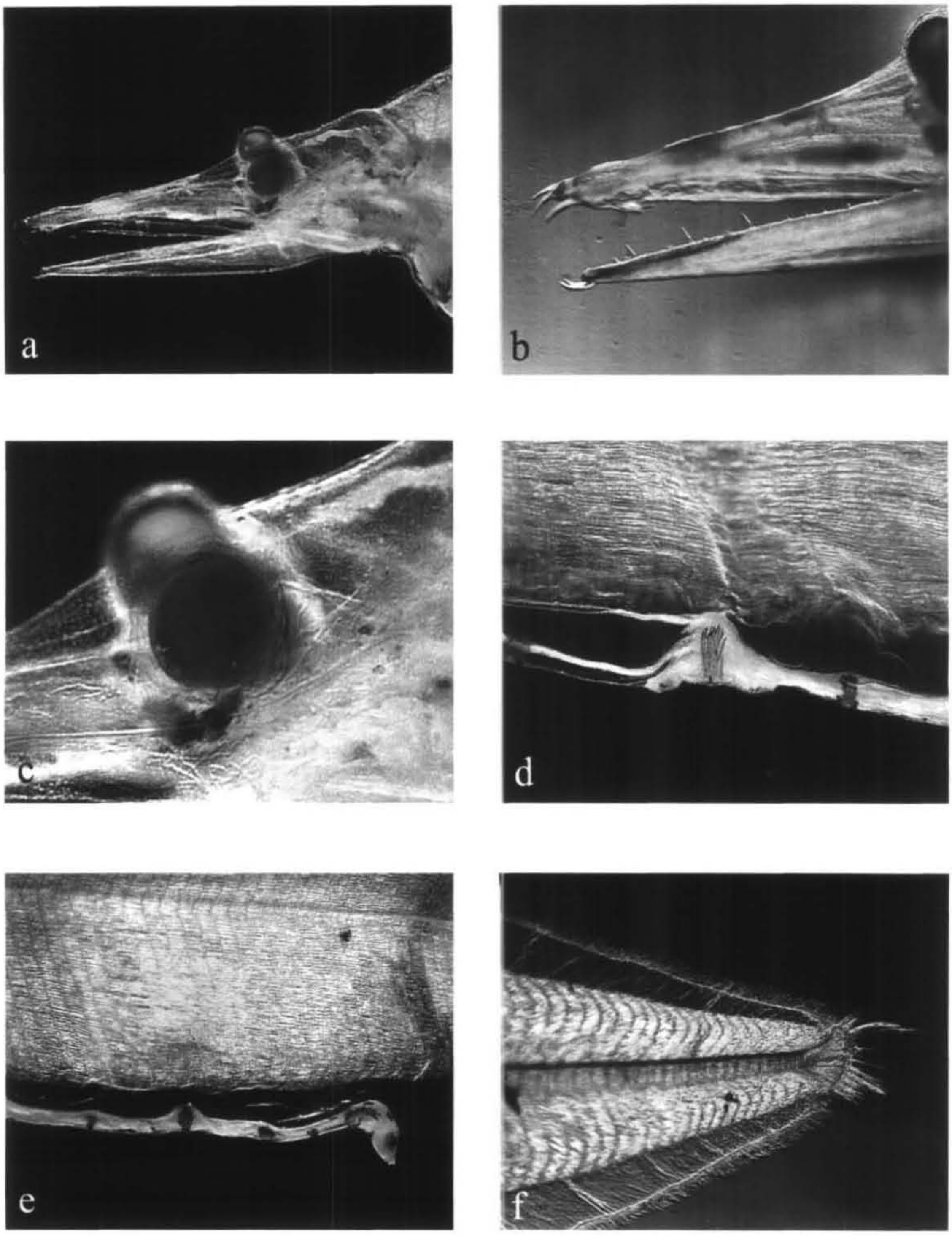


PLATE 23. Synaphobranchidae- Type A
a. Head b. Teeth c. Eye d. Pigmentation on intestine e. Intestine f. Tail

Body spindle shaped; head elongate (Plate24. a); tail moderately pointed; snout long and straight; cleft of mouth straight, not reaching to the level of eye; nasal organ not well developed; all fins except the caudal fin in the specimen examined was poorly developed, so unable to make any observations; caudal fin with discernible rays; eye telescopic (Plate24. b); dentition as follows: each half of upper jaw with a short, antero-dorsal tooth, a slightly curved, slender clasping tooth followed by two large teeth and 11 small teeth; lower jaw bears on its each half a curved, sharp tooth in its tip followed by six large teeth and six small teeth; intestine more than one-half of body length with seven swellings or thickenings (Plate24. f).

A few pigment spots on the anterior margin of the upper jaw; base of the stalked eye ball pigmented; five stellate, branching, sub cutaneous chromatophores behind the eye (Plate24. c); highly branching pigment network in and around the heart region (Plate24. d); single, stellate, branched chromatophore on the ventral side of gut ahead to the gastric region, another two between the first and second thickening and one each between the rest of the thickenings: branched, filiform chromatophores on all the seven thickenings (Plate24. e); 5-6 stellate, branched chromatophores were also present on the dorsal side of the thickening near the anus; hypurals well developed (Plate24. g).

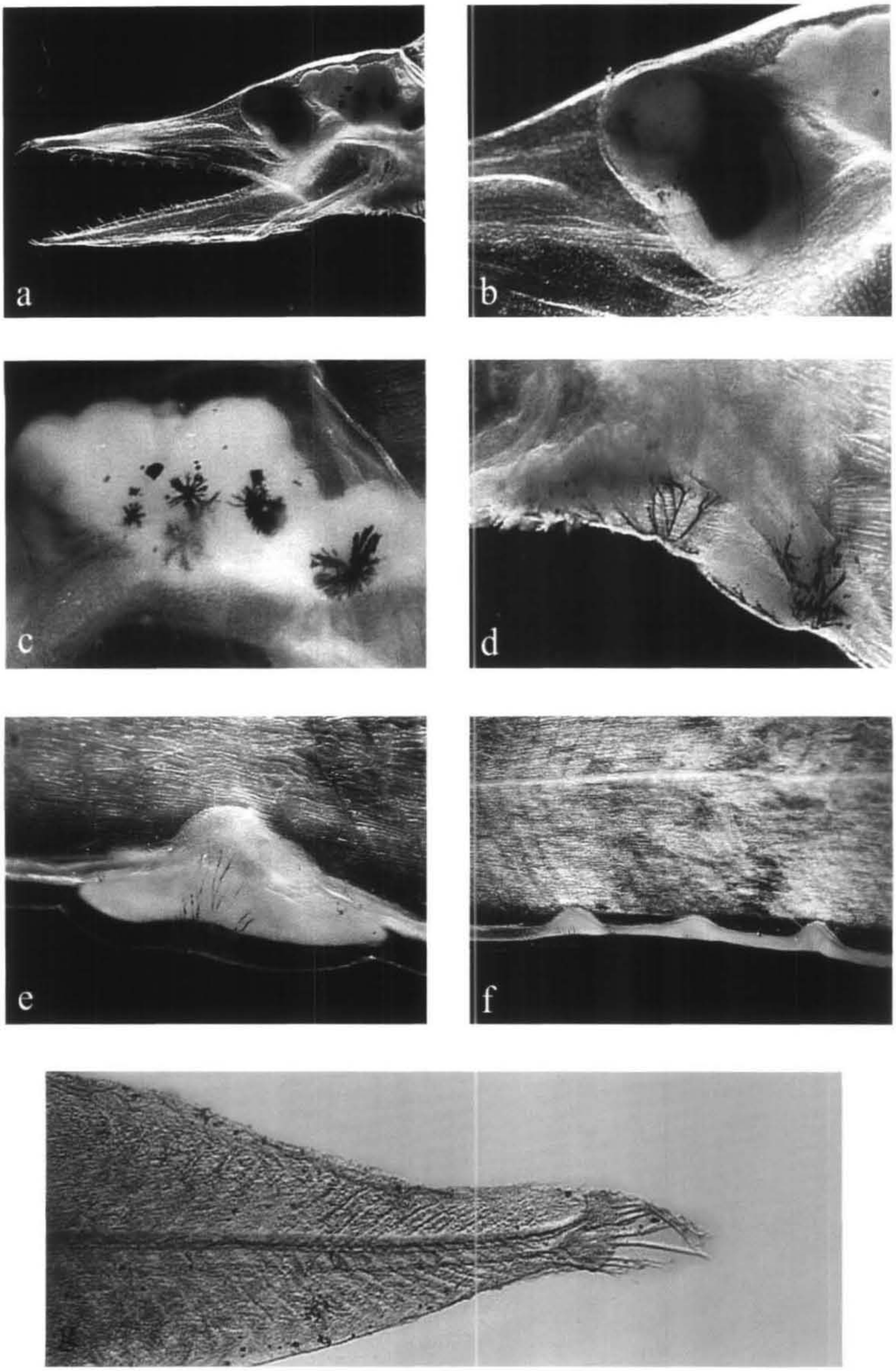


PLATE 24. Synaphobranchidae- Type B
a. Head b. Eye c. Pigmentation behind eye d. Pigmentation on heart e. Pigmentation on gastric region f. Intestine g. Tail

Metamorphosing stages of *Congrellus anago* (non Temm.and Schleg.)

The leptocephali of *Congrellus anago* (non Temm. and Schleg.) were first recorded from Indian waters by Gopinath (1946). The description was based on a collection of larval and post larval fishes found along the Trivandrum coast, south west coast of India. The same author (1950) described it again from the above area. Earlier works were based on the collections from the coastal waters, where as the present work is on the samples mostly from the deeper waters (>100m). So far no attempt has been made to study the metamorphosing stages of *Congrellus anago* (non Temm.and Schleg.) and the present study is based on the collection from the Deep Scattering Layer (DSL) of the south west coast of India. Metamorphosing stages are as described below:

Stage – A

The larva is long and transparent, measuring about 142mm in length. Maximum height of the body excluding the vertical fins is 13mm, which is 10.9 times in length. Head is comparatively short and is 35.5 times in length. Snout short, bluntly pointed and 2.9 times in head. Eye diameter 1.09mm, which is 3.6 times in head. Cleft of mouth oblique, straight not reaching the centre of eye. Jaws are provided with pointed, forwardly directed teeth. The dental formula is I+I+9+8 / I+9+4. Each half of the upper jaw with a short, antero-dorsal grasping tooth and a fang like long tooth. Other teeth are in two groups- first group of nine large teeth followed by eight small teeth in the second group. The lower jaw possesses a single large tooth in the tip followed by nine large teeth and four small teeth. Pectoral fin feeble with indistinct rays. Dorsal and anal fins short and restricted to the posterior, with both the fins originating from the same myomere. Dorsal fin has 29 rays and anal fins 31 rays. Caudal region bluntly pointed with 6 distinct rays. There are about 118 myomere in the body of which 108 are pre anal and 10 post anal. Intestine long and straight, extending to more than 3/4th length of larva.

Pigmentation in the larva is very conspicuous. Single, mid dorsal row of stellate chromatophores starting from the 5^{th} myomere and continuing till the origin of dorsal fin. Lateral pigmentation in the form of minute melanophores outlining the myosepta immediately below the mid line forming a series of short, diagonal lines from head to tail. Closely packed chromatophores on the dorsal side of the intestine posterior to the gastric region, anterior to which it is on the ventral side of the gut. Single pigment spot below the heart on the anterior part. A few of the posterior most dorsal fin rays and the caudal fin rays have pigmentation on its base. Majority of the anal fin rays with pigmentation.

Stage – B

This is the growing stage of larva and there is a slight increase in the length and also the maximum body height. There is no predictable variation in the length of head. A slight decrease in the length of snout and an increase in the diameter of eye are noted. There are about 36 and 47 countable rays on dorsal and anal fin rays, respectively. Total myomeres in this stage is 114 with 104 pre anal myomeres, indicating the shifting of anus and 10 post anal myomeres. Origin of dorsal fin in this stage is one myomere behind the anal fin origin. Pectoral fin still with indistinct rays. Dental formula same as that of Stage A.

There is no change in the pigmentation of larva and it generally confirms with that of the previous stage, except for a few chromatophores (12-13) below heart.

Stage – C

This stage the larva has again shown an increase in the length though the height remains the same. There is no variation in the head length also. As in the previous stage there is a reduction in the snout length. Fin rays are distinct with 40 and 47 rays on dorsal and anal fins, respectively. Eye diameter is same as that of Stage A, showing a slight decrease from that of Stage B. Total myomeres as same as in the previous stage, of which 104 are pre anal in position. Except for three distinct pigment spot below the heart, pigmentation is same as in the earlier two stages.

Stage – I

This is the edentulous stage indicating the commencement of metamorphosis; the only noteworthy change from the last three stages is the complete shedding of all larval teeth. There is a slight increase in the height of larva than the previous two stages. Head length remains the same though there is a slight reduction in the snout length. There are about 117 distinct myomeres of which 101 are pre dorsal and 96 pre anal, indicating the shifting of dorsal fin and anus, respectively. There are about 60 and 93 rays on dorsal and anal fins.

Pigmentation of larva shows no variation and is almost the same as in the previous stages, except for the absence of pigments near the heart. The tail has become more tapering than that of earlier stages. The larva in this stage has the maximum length (165 mm).

Stage – II

A notable difference from that of the previous stage is the reduction in length (146 mm), which is a characteristic change during metamorphosis. There is a slight reduction in the height also. Dorsal, lateral and ventral pigmentations are same as in the earlier stages. Pigmentation on the base of all fin rays except for pectoral fin. Caudal region has become slightly opaque. Tail becoming more tapered with the anus and dorsal fin advancing forward. There are about 52 and 90 countable dorsal and anal fin rays, respectively.

Stage – III

This stage is again charaterised by the further reduction in length (132 mm), though the height and head length remaining the same as in the previous stage. This stage has the minimum snout length and there is a slight increase in the diameter of eye. There are about 112 myomeres, which is the minimum among all the stages. Dorsal fin and anus further shifting forwardly. There are about 61 and 102 dorsal and anal fin rays. Pectoral fin with indistinct rays. Seven branchiostegal rays discernible.

No trace of dorsal pigmentation noticed in this stage (might have fallen off, mention in the materials and methods). Lateral and ventral pigmentation same as in earlier stages. Pigmentation on all fin rays except the pectoral fin. Anus and dorsal fin has shifted forward. Thickness of the specimen has increased and the caudal region is opaque.

Stage – IV

This stage represents the smallest larva of all the previous stages with reduction in length (129 mm) and height (12 mm). There is a noticeable increase in length of head and also the shape has changed considerably. There is an increase in the length of snout and also in the diameter of eye. There are about 55 and 107 countable dorsal and anal fin rays. Total myomeres is 114 of which 76 are pre anal, further indicating the shifting of anus to a more anterior position. Dorsal fin origin also shifted anteriorly. Pectoral fin size slightly reduced. No trace of any adult dentition. Caudal region has become more tapered. Dorsal, lateral and ventral pigmentation present as in the earlier stages. Pigmentation on the base of dorsal, anal and caudal fin rays.

	Stage A	Stage B	Stage C	Stage I	Stage II	Stage III	Stage IV
Total length (mm)	142	149	159	165	146	132	129
Maximum height (mm)	13	14	14	15	13	13	12
Length of head (mm)	4	4	4	4	4	4	5
Length of snout (mm)	1.344	1.312	1.248	1.184	1.152	1.024	1.184
Diameter of eye (mm)	1.088	1.152	1.088	1.184	1.12	1.152	1.184
Caudal fin rays #	3+3	3+3	3+3	4+3	3+3	3+3	4+3
Dorsal fin rays #	29	36	40	60	52	61	55
Anal fin rays #	31	47	47	93	90	102	107
Total myomeres	118	114	114	117	113	112	114
Pre anal myomeres	108	104	104	96	87	80	76
Pre dorsal myomeres	108	105	104	101	95	92	89
Teeth	$\frac{I+I+9+8}{I+9+4}$	$\frac{I+I+9+8}{I+9+4}$	$\frac{I+I+8+8}{I+10+2}$	Nil	Nil	Nil	Nil

 # Only distinct rays counted

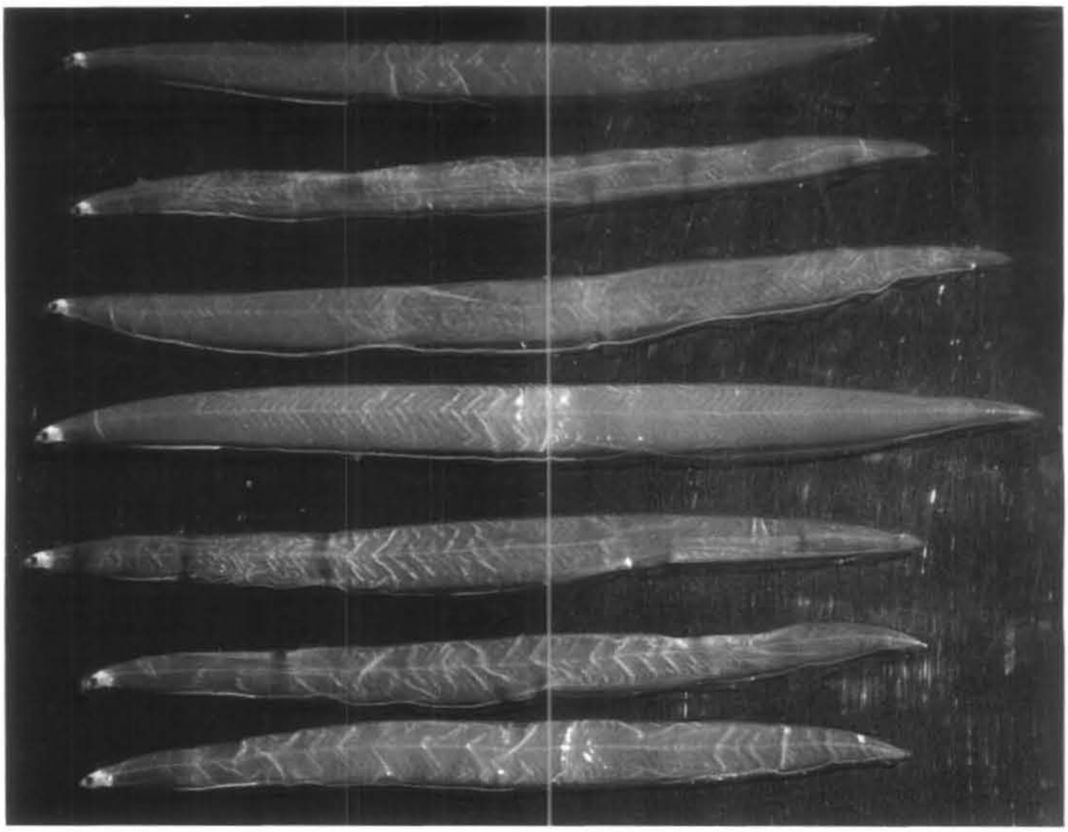


PLATE 25. Metamorphosing stages of *Congrellus anago* (non. Temm. and Schleg.)

Distribution and abundance of Leptocephali

Quantitative abundance of Leptocephali

The general observation made on the occurrence and abundance of the leptocephali showed that numerically they formed one of the major components of the nekton in the Deep Scattering Layer (DSL). Leptocephali were found distributed extensively all along the west coast of India. It was present in 148 IKMT stations (81 night and 67 day) out of a total of 172 IKMT stations sampled in the west coast of India during the period from May 1998 to June 2001. The location of stations (day and night) from where leptocephali were obtained is given in Fig.5. The quantitative estimates have been made as number per1000m^3 of water. The occurrence of leptocephali varied from a low of 0.04 to a maximum of 18.32. no./1000m^3 per haul. Comparatively the night biomass was high (154.95) than the day (57.32). In general, the night and day biomass constituted 73% and 27%, respectively, of the total biomass (212.27) on the west coast of India.

Geographical variation

The leptocephali were found distributed widely in the west coast of India from the coast to the deep sea. They are distributed evenly (below 5/1000m^3 for one degree square) with three high density pockets (above 5) as shown in Fig.6. The highest abundance of 18.32 was recorded from the area 12°30 – 71°29. Only five stations yielded more than ten. The next abundance of 5 – 10 were observed only in 9 stations. The rest of the catch was below five. The important areas of abundance in the regions where the catch per haul was more than 5 numbers are given in Table 1.

Latitudinal abundance

The whole area investigated was divided into latitudes from 6° - 21°N. In general it was found that the leptocephali numerical abundance was more pronounced in 15° - 19° N. Another good concentration was located in 8° - 10°N and

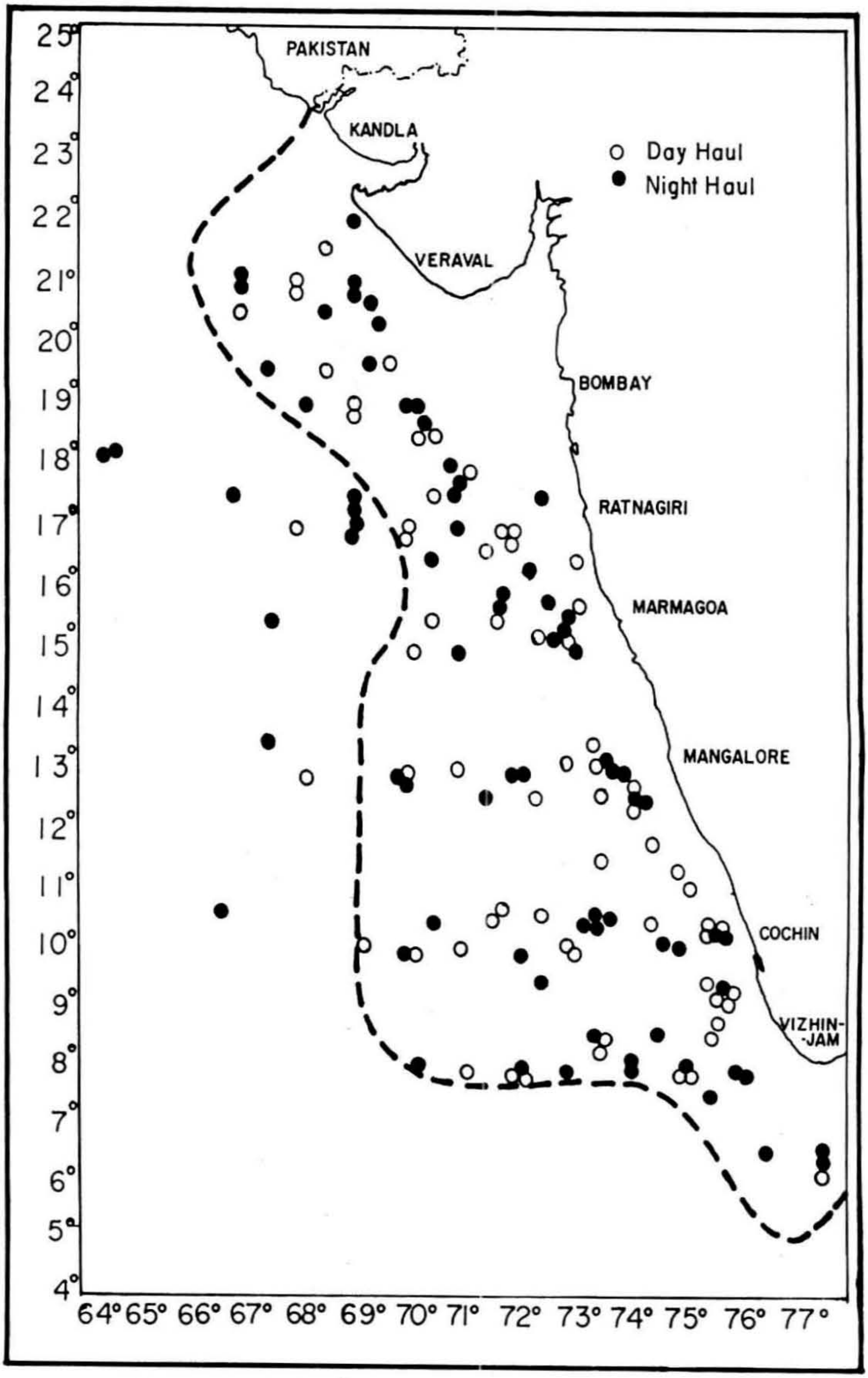


Fig: 5 I K M T Stations in the West Coast of India

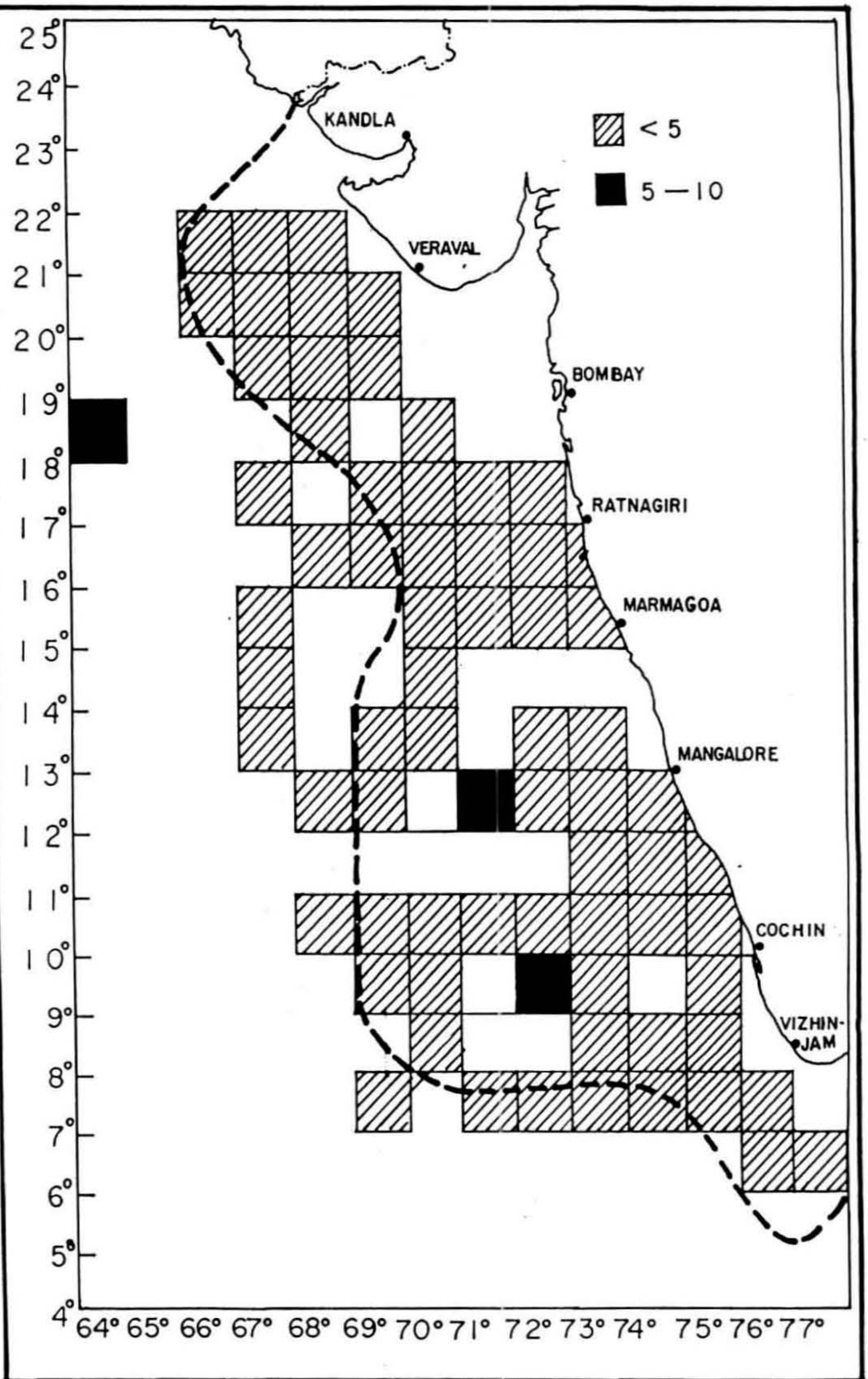


Fig. 6 Distribution and abundance of Leptocephali (No /1000 m^3) in the West- coast of India

Table 1: Major area of abundance of Leptocephali in the West coast of India

Station No.	Area of operation	Latitude	Longitude	Depth of operation (m)	Depth of bottom (m)	No. of Leptocephali	No./1000m^3
116	SW	12^0 30	71^0 29	60-70	1584	509	18.32
17	SW	9^0 29	72^0 30	70	1810	373	13.42
503	NW	18^0 59	70^0 00	50	254	331	11.92
21	SW	10^0 29	73^0 30	10	1926	279	10.04
101	NW	18^0 07	64^0 35	30-145	1603	279	10.04
499	NW	16^0 59	71^0 51	185	227	242	8.71
2	NW	17^0 23	69^0 30	60	3359	223	8.03
158	NW	19^0 33	69^0 20	35	1182	215	7.74
497	NW	17^0 00	70^0 00	320	3476	189	6.80
104	NW	18^0 27	70^0 30	40-80	332	184	6.62
504	NW	19^0 00	68^0 58	320	2809	182	6.55
149	NW	17^0 30	70^0 59	10-20	1741	150	5.40
103	NW	18^0 23	70^0 10	40-80	1345	140	5.04
138	NW	15^0 19	72^0 52	15-35	229	140	5.04

also in 12°N (Fig.7). Latitude wise the leptocephali maximum was recorded in 18°N (4.06) off Bombay followed by 19° and 17°N (3.47 and 2.74).

Day – night variation

A comparative study of the day and night variation of leptocephali was carried out in the entire area of investigation. The analysis revealed that 27% of the total leptocephali collected was taken during day while the night samples took a share of 73% there by showing more than three times number of leptocephali in the day samples.

a) Latitudinal variation

The night catch was comparatively high in most of the latitude with a range of 32.74% to 96.15%. The highest percentage of 96.15 was recorded at 9° latitude followed by 88.96% at 12° latitude. In the day it was 16° latitude that had the highest percentage (67.26%) and the lowest by 9° latitude (3.85%). The latitude wise abundance in numbers for day and night are presented in Fig.8.

b) Month wise abundance

The monthly catch percentage varies from a low of 7.3% to a high of 92.68%. Figure 9 shows that the night catches constituted for the bulk of the catch. It shows a variation from a low value of 34.41% (March) to a high of 92.68% (May). In the day it was the month of May with a lowest share of 7.32% and a highest share of 65.59% in March. (Fig.9)

c) Vertical abundance

The vertical abundance of leptocephali was maximum during night in the operational depth range of 50 – 100m (89.26%) where as a low of 23.30% in the 100 – 300m range. The daytime abundance indicates a very low of 10.74% in the 50 – 100m depth of operation and a high at 100 – 300m (76.70%). (Fig.10) The leptocephali were present up to a depth of 750m.

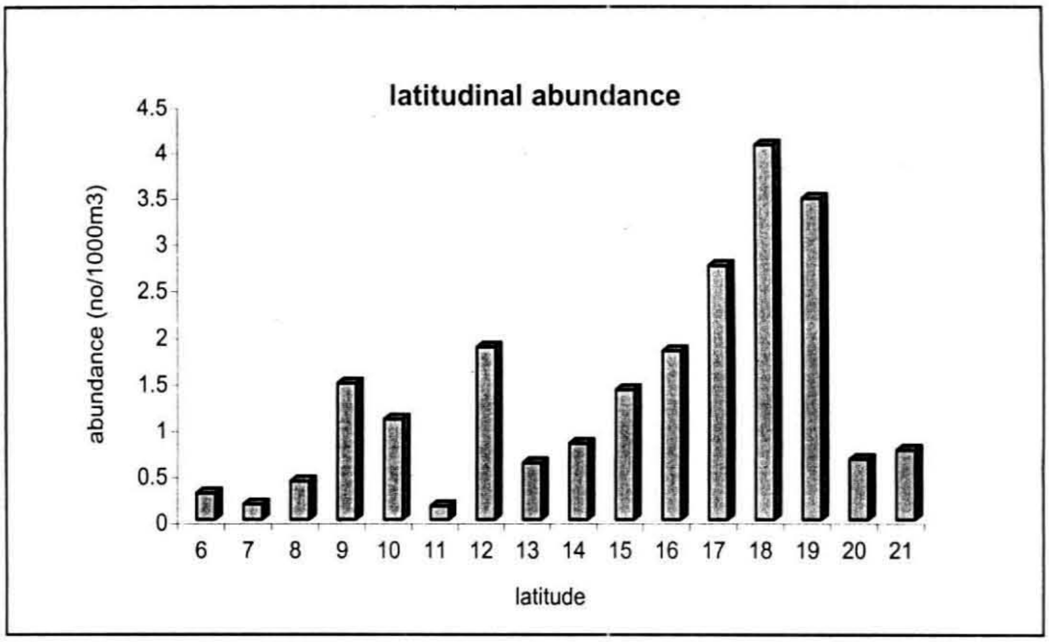


Fig. 7. Latitudinal abundance of Leptocephali in the west coast of India

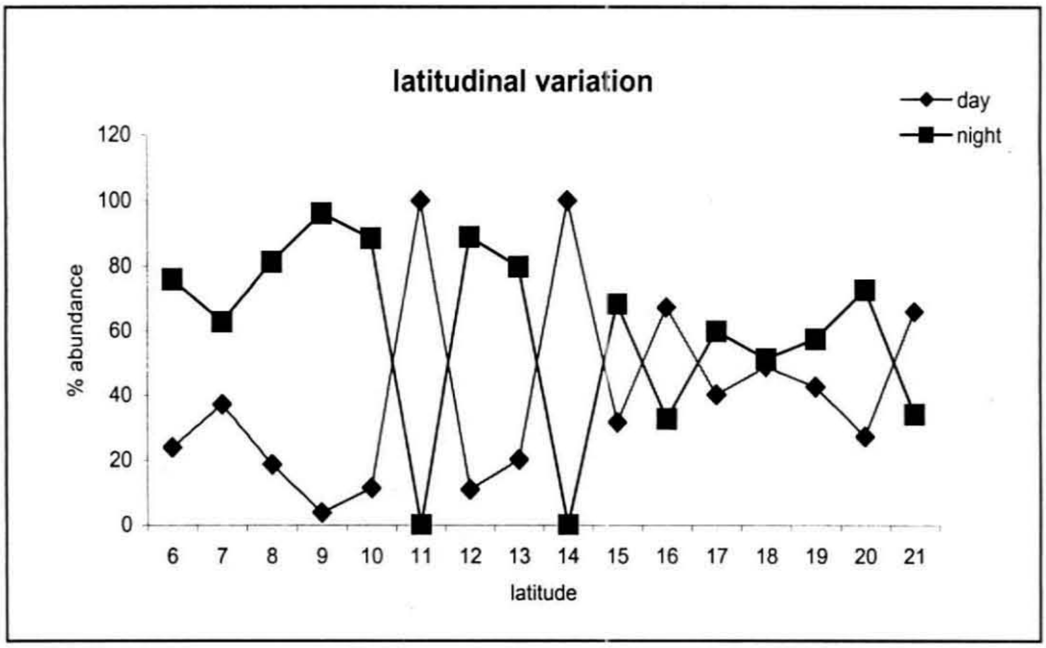


Fig. 8. Latitudinal variation (day and night) of Leptocephali

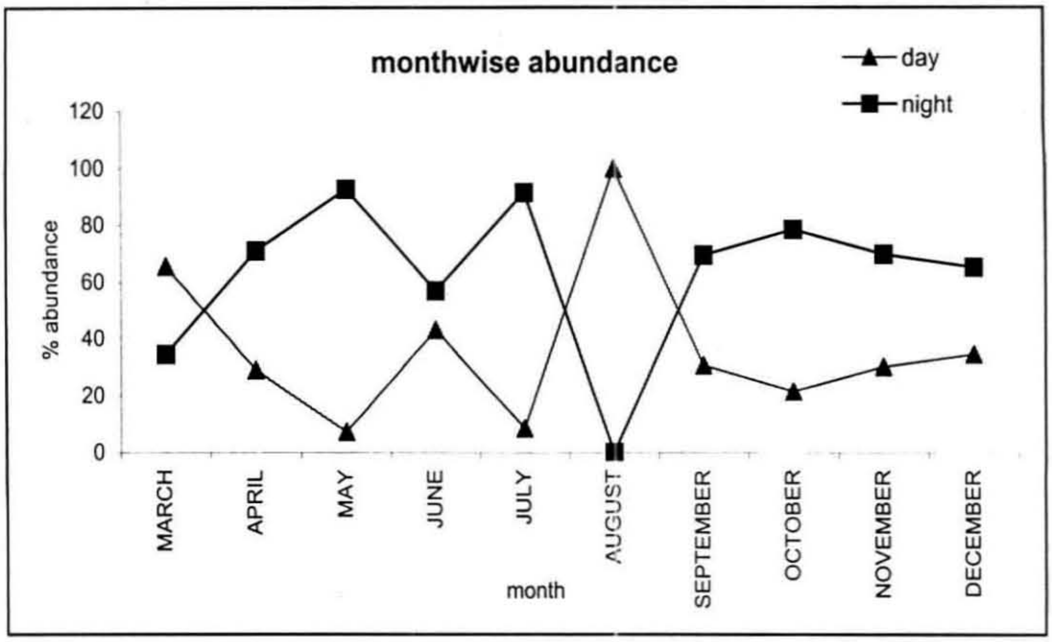


Fig.9. Month wise abundance (day and night) of Leptocephali

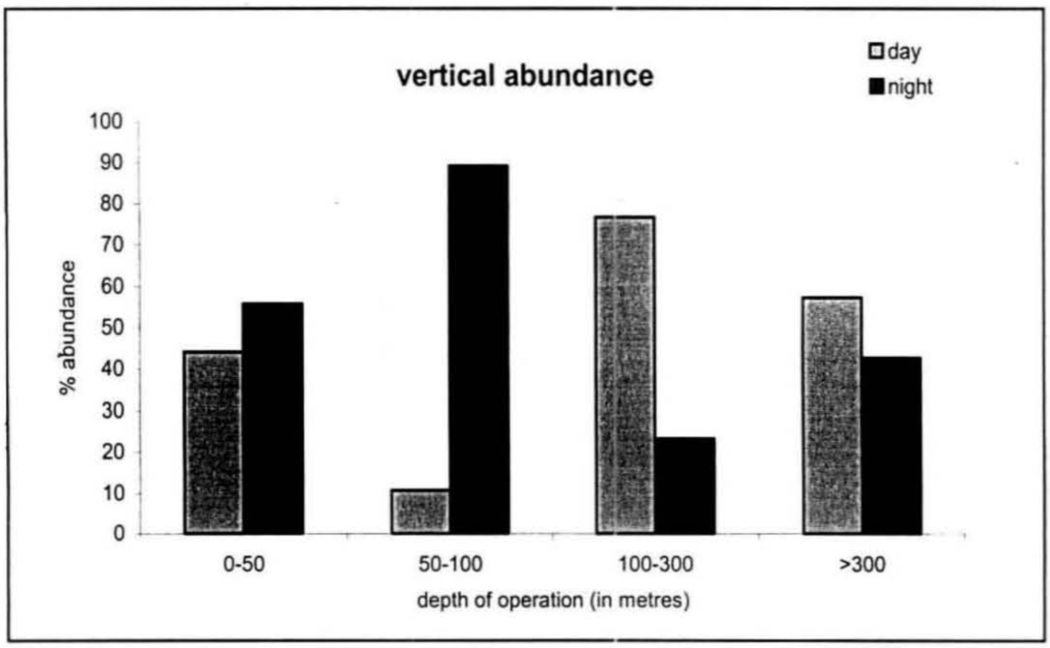


Fig.10. Vertical abundance (day and night) of Leptocephali

d) Horizontal abundance

The analyses of the samples revealed an increasing trend up to the 1000 – 3000m depth zone (77.70%) during night, after which it decreases. The nighttime catch showed a lowest figure in the 0 – 200m depth zone (33.64%). The day catch was low between 1000 – 3000m and recorded a high value of 66.36% in the 0 – 200m depth zone. (Fig.11)

e) Diurnal variation

The leptocephali were maximum during the early hours of the day (00 00 – 04 00Hrs), which accounted for the bulk of the catch (51%). It was followed by 16% between 20 00 – 00 00Hrs and 12% between 04 00 – 08 00Hrs. Rest of the day's hauls constituted to less than 10% of the total abundance (Fig.12).

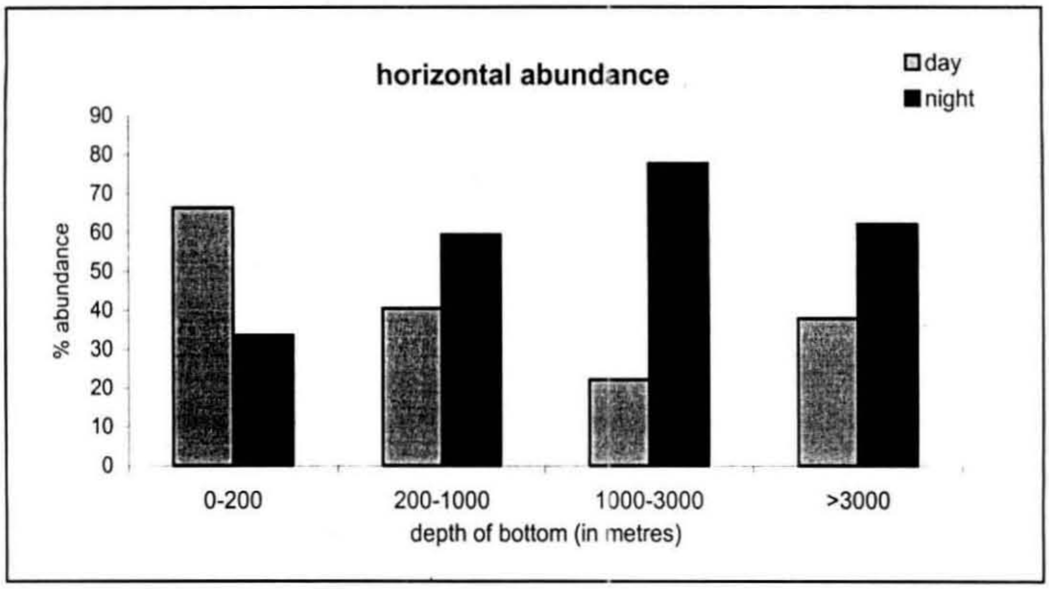


Fig.11. Horizontal abundance (day and night) of Leptocephali

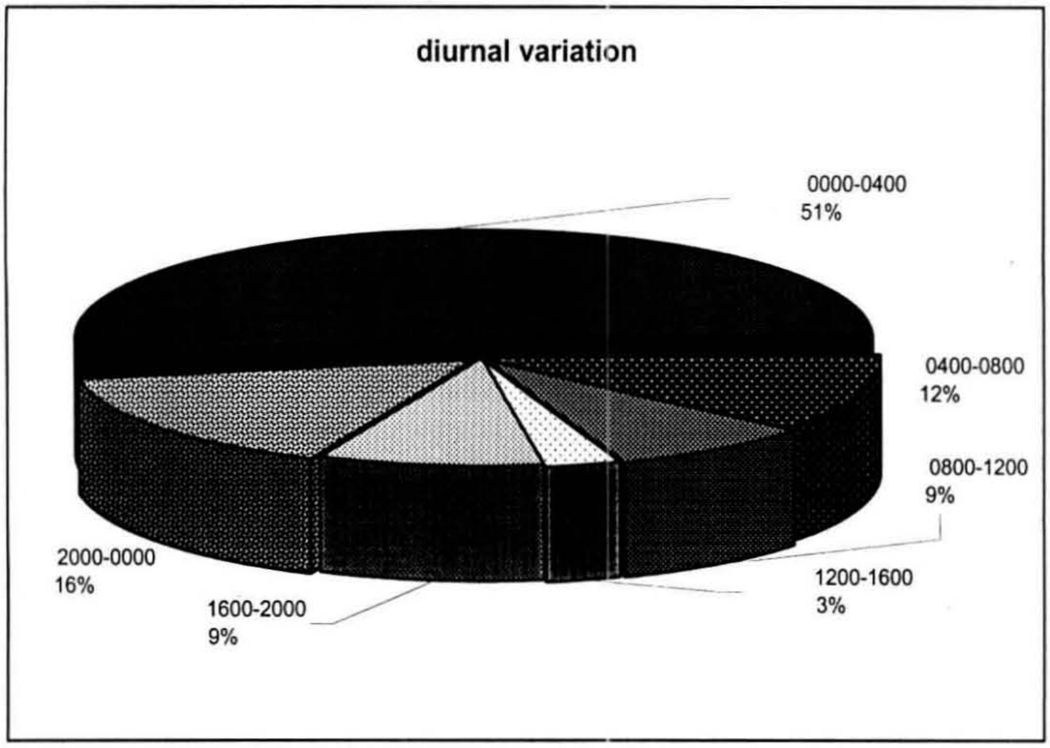


Fig.12. Diurnal variation of Leptocephali

Distribution and abundance of major families of Leptocephali in the southwest coast of India

The resource distribution and abundance of leptocephali of the west coast of India was dealt in the previous section, where as, this section deals with the leptocephali of the southwest coast of India. The study was carried out in an area below 15°N latitude and 78°E longitude. A total of 105 IKMT operations were carried out of which 84 were positive stations (80%) for leptocephali. The maximum number per haul per $1000m^3$ was 18.32 at 12°30N latitude and 71°29E longitude and with an average of 0.91 numbers. Leptocephali belonging to five major families constituted the IKMT samples from the south west coast of India viz. Congridae, Ophichthidae, Muraenidae, Nemichthyidae and Synaphobranchidae.

The numerical abundance of leptocephali in the south west coast of Indian EEZ shows that the maximum number was contributed by the family Congridae (44%) followed by Ophichthidae (30%) and the rest by other three families and some unidentified specimens coming under the order Anguilliformes, Elopiformes (Fig.13). The total biomass (no/$1000m^3$) of the south west coast (76.09) accounted to about 35.85% of the total west coast leptocephali. In general, the leptocephali distributed evenly in the south west coast of India with a catch of <5 number and having only two pockets of more than 5 (5-10) at off Cochin and off Mangalore (Fig. 6).

Latitude wise distribution clearly indicates that the leptocephali were most abundant in 12° latitude (average 1.87 number). Generally 9°-12° latitude contributed about 82% of the catch. Table 2 shows the percentage of their numerical abundance in the south west coast.

Seasonal abundance was more during monsoon with an average of 5.84 number. Numerically the catch was better during May (44.75%), followed by July (27.86%). The monthly catch (in number) percentage is presented in Table 3.

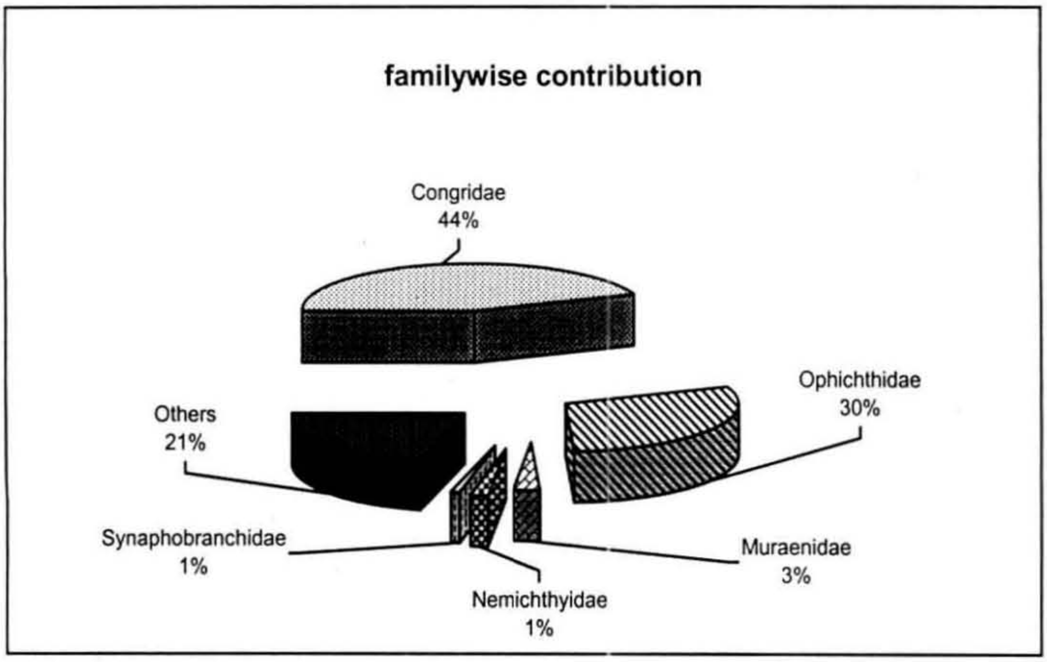


Fig.13. Family wise percentage contribution

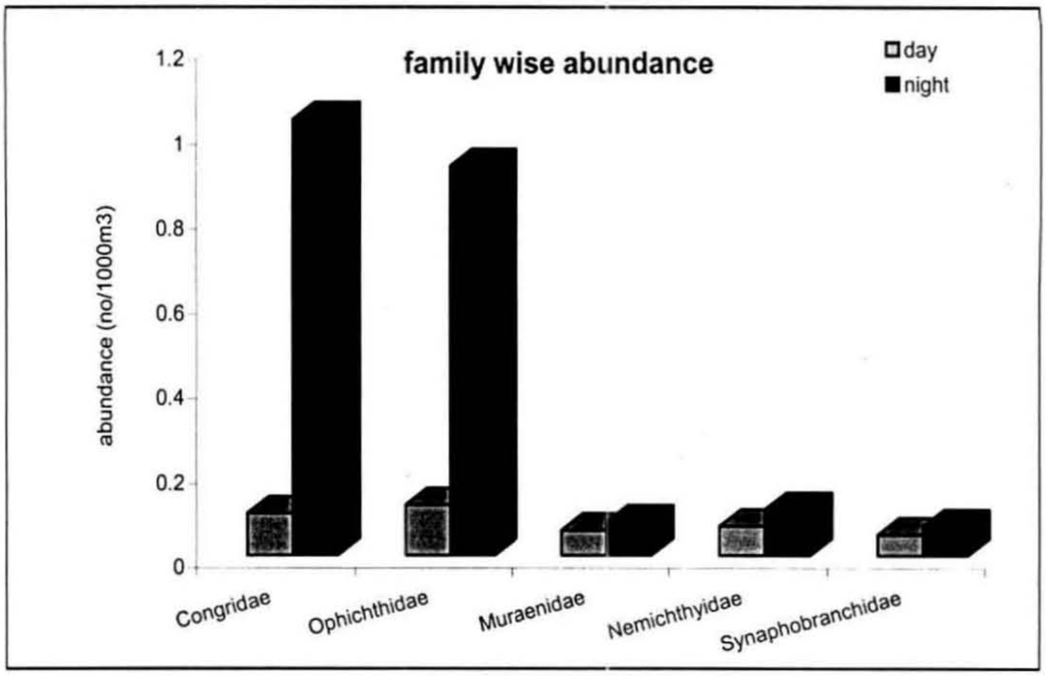


Fig.14. Day and night abundance of different families of Leptocephali

Table 2. Latitude wise abundance

Latitude	% Abundance
6	1.51
7	2.98
8	5.53
9	19.49
10	29.94
11	0.76
12	31.93
13	5.68
14	2.18

Table 3. Monthly abundance

Month	% Abundance
April	2.84
May	44.75
June	1.47
July	27.86
September	4.59
October	5.25
December	13.25

Table 4. Vertical abundance (day and night)

Depth of Operation (m)	% Abundance Day	% Abundance Night
0-50	3.90	96.10
50-100	6.07	93.93
100-300	74.05	25.95
>300	66.47	33.53

Table 5. Horizontal abundance (day and night)

Depth of Bottom (m)	% Abundance Day	% Abundance Night
0-200	100	0
200-1000	30.20	69.80
1000-3000	7.98	92.02
>3000	40.85	59.15

The numerical abundance of leptocephali in the vertical depth range (depth of operation) shows that it was more on the 50 – 100m depth range (59.87%), where as the horizontal distribution was maximum in the depth zone between 1000 – 3000m (82.97%). In general, a 24hour period abundance of leptocephali shows a maximum abundance between 20 00 – 00 00 hours in the southwest coast of India.

Day-night variations

Day and night variations in the catches were very clear, with the night catch contributing a major share of 87% (66.2) and day a meager 9.89 accounting to only 13 % of the total. Diurnal variation also shows that the night catches were more pronounced for the two families viz. Congridae and Ophichthidae (Fig.14). The night catch of the family Congridae constituted about 92.11% of the total congrid catch and Ophichthidae forming 92.86% of the total ophichthid catch. Day and night variations for the other three families viz. Muraenidae, Nemichthyidae and Synaphobranchidae were less in comparison with the values less than 0.2 numbers.

a) Latitudinal variations

Latitude wise variations in the day and night catch (percentage) shows that the night catch was maximum in general with the 9° latitude contributing the highest (94.42%) followed by 12° and 6° with 92.74% and 90.63%, respectively. The general trend shows that the night catch was comparatively high in comparison with little variation. The day catch was low with a maximum of 39.68% in the 7° latitude (Fig. 15). In latitudes 11° and 14° the night catch was nil as there was no IKMT operation.

b) Monthly variations

A study of the monthly day-night variations in catch shows that the month of May contributed to the highest percentage of the night catch (93.76%) followed by July (91.51%). The day maximum was in the month of September with a share of

43.30% (Fig.16). General trend shows that the night catch contributed to more than 50% of the total catch in each month.

c) Vertical abundance

The depth wise (depth of operation) percentage contribution of the day and night shows that the night contribution was high in the depth range of 0 – 50m with a share of 96.10% followed by 50 – 100m (93.93%) (Table.4). The day was high in the 100 – 300m depth range. The figure (Fig.17) shows that the leptocephali was abundant in the depth up to 100m during night and in 300 – 400m during day. It was found in a maximum depth of 750m. A higher numerical abundance of 279, 509 and 273 numbers were found with in the depth range of 75m.

d) Horizontal abundance

Diurnal variation studies along the different bottom depths show that the depth zone of 1000 – 3000m contributed the maximum night catch (92.02%), where as the daytime contribution was high above the 3000m zone (Table 5).

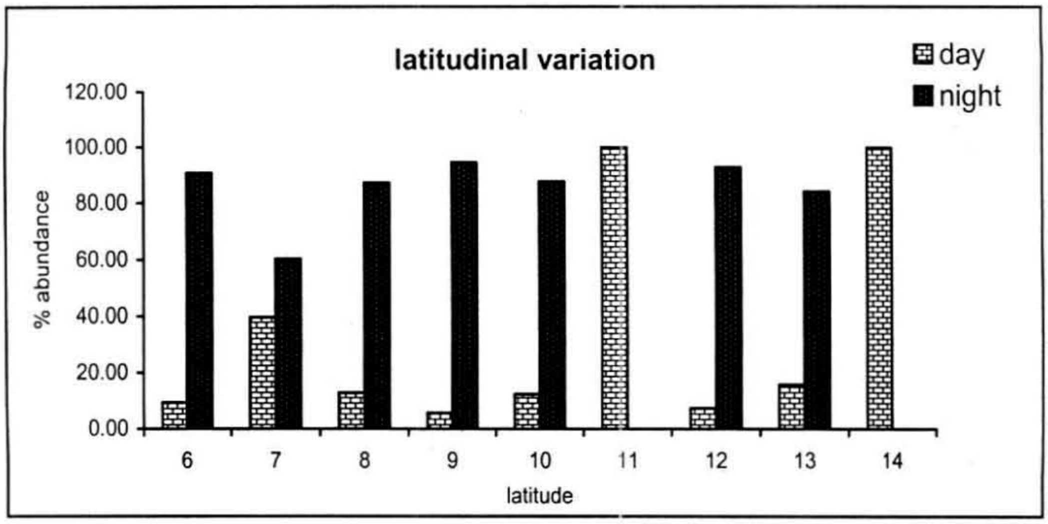


Fig. 15. Latitudinal variation (day and night) of leptocephali in the southwest coast of India

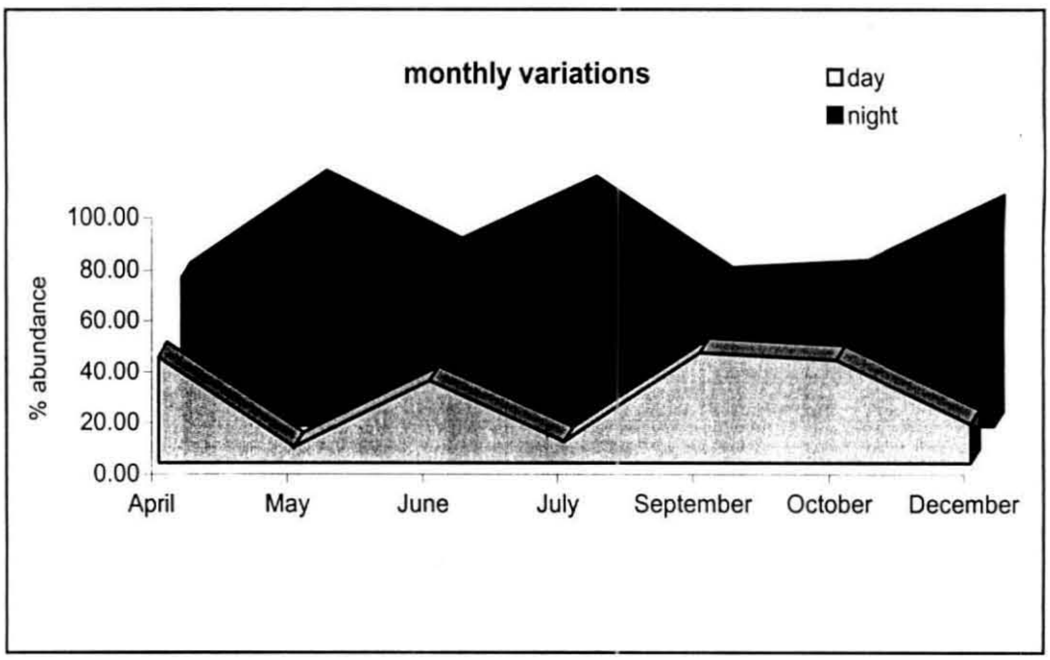


Fig.16. Monthly variation (day and night) of leptocephali in the southwest coast of India

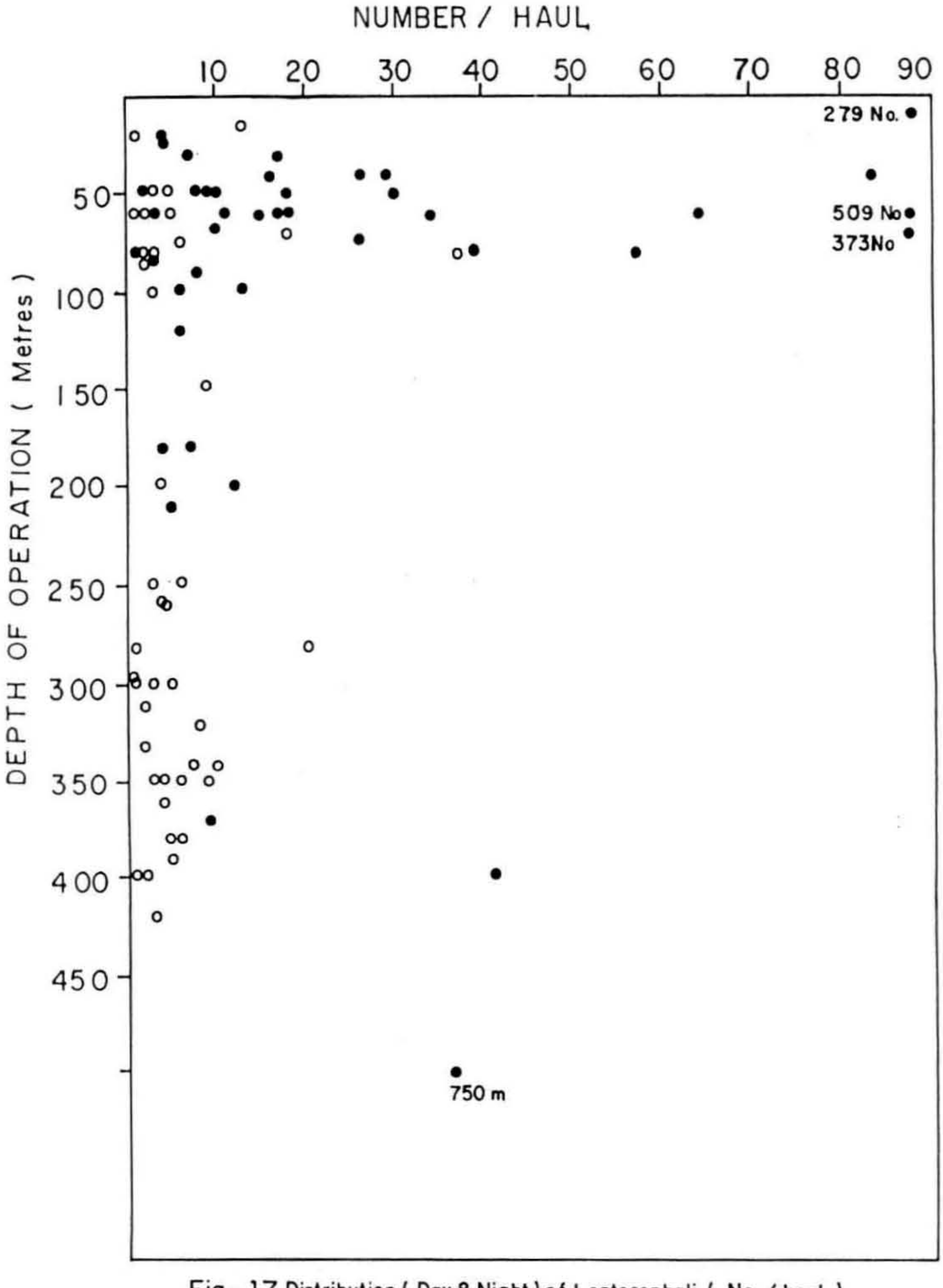


Fig: 17 Distribution (Day & Night) of Leptocephali (No. / haul) in the South West Coast of India

Family – Congridae

Leptocephali of the family Congridae formed the largest group among the five families in the south west coast of India. It was present on 57 stations out of the 84 stations sampled in the area of study accounting to about 44% of the total southwest coast leptocephali. It was distributed evenly with one dense pocket off Cochin. (Fig.18)

Latitudinal abundance clearly reveals that the congrid leptocephali was mainly concentrated in the two latitudes viz. 9° and 10° (79.18%) with a maximum in the 10° accounting to 40.45% of the total Congridae catch in the south west coast of India. (Table 6)

Monthly catch proposition shows that the bulk of the catch was made during May, which contributed, to about 80.04% of the total congrid catch, followed by July (8.48%). (Table 7)

The percentage abundance of congrid leptocephali in the different depths of operation is given in Table 8. It clearly indicates that the maximum concentration in the depth ranges of 0-50m and 50-100m, with the 50-100m depth range contributing the major share (55.90%).

Studies on the horizontal distribution (Depth of Bottom) of the family Congridae revealed that the maximum abundance was between the 1000-3000m depth zone which contributed 93.03% of the congrid catch. It was also noted that there was a complete absence of this family in the 0-200m depth zone. (Table 9)

Diurnal variation studies show that the congrid leptocephali were abundant maximum during the late night hours (20 00 – 00 00hours) with a percentage contribution of 82.19%.

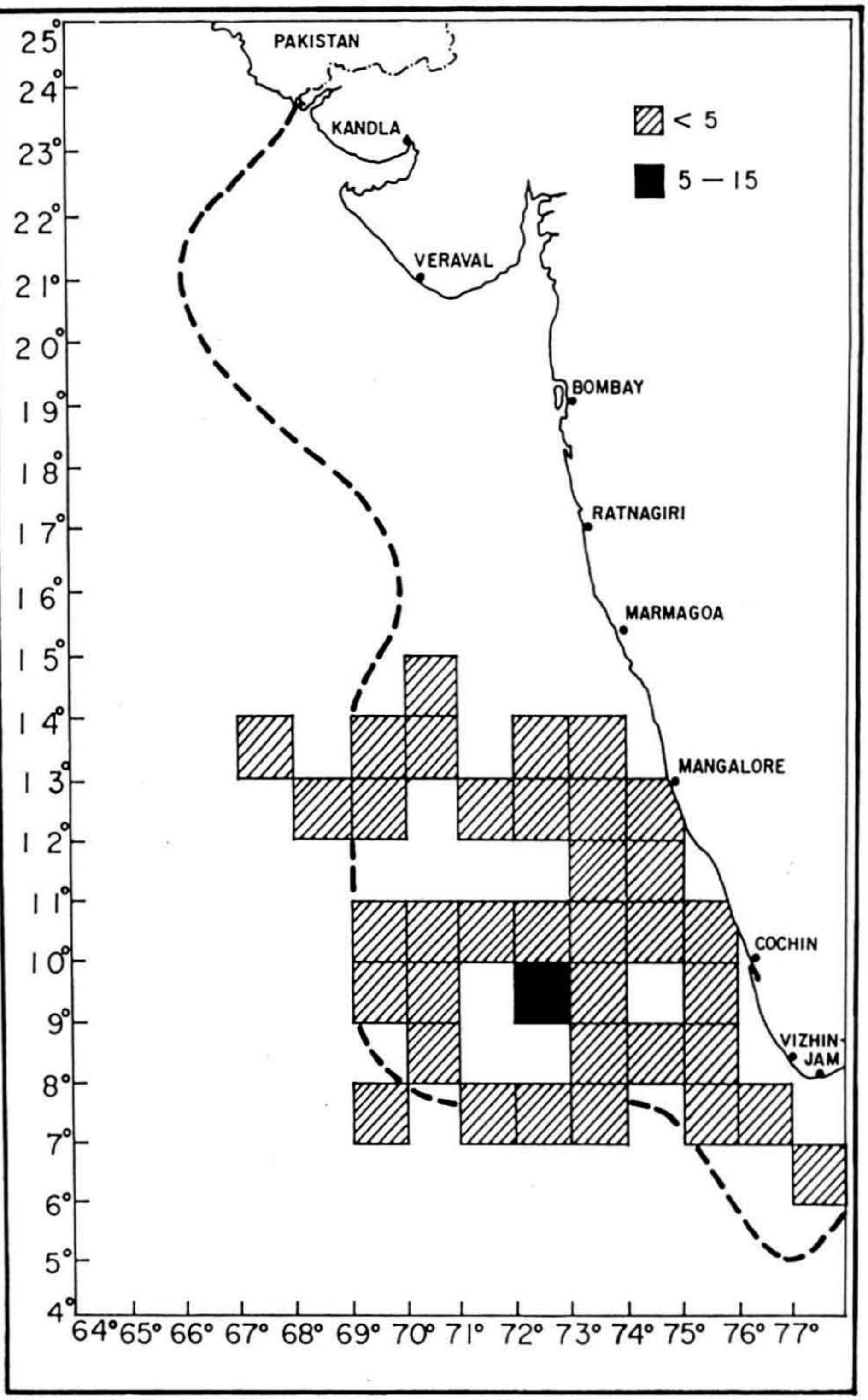


Fig: 18 Distribution and abundance ($No/1000m^3$) of Congridae in the South West coast of India

Table 6. Latitude wise abundance

Latitude	% Abundance
6	0.54
7	2.79
8	4.61
9	38.73
10	40.45
11	1.50
12	9.44
13	1.39
14	0.54

Table 7. Month wise abundance

Month	% Abundance
April	0.64
May	80.04
June	1.82
July	8.48
September	2.58
October	0.43
December	6.01

Table 8. Vertical abundance

Depth of Operation (m)	% Abundance
0-50	39.27
50-100	55.90
100-300	1.72
>300	2.90

Table 9. Horizontal abundance

Depth of Bottom (m)	% Abundance
0-200	0
200-100	2.15
1000-3000	93.03
>3000	4.83

Day-night variation

a) Latitudinal variation

The study revealed that the night catch was fairly high in comparison along the different latitudes. The share of the night catch was contributed maximum from the 9° latitude (98.34%), followed by 10° latitude with a share of 94.16%. The contribution to day catch was more at the 13° latitude (30.77%). (Fig.19)

b) Monthly variation

The monthly catch statistics shows a variation of 2.41% to 97.59% in the day-night composition. Results of the studies revealed that the month of May accounted for the maximum contribution to the night catch (97.59%), followed by December (82.14%). A general trend shows maximum catch during the night. Daytime contribution was maximum during the month of April (83.3%). (Fig.20)

c) Vertical distribution

A comparative study of the day and night distribution of congrid leptocephali along the different depths of operation revealed that the night catch was maximum at the depth range of 50 – 100m forming 96.35%, followed by 0-50m range (95.63%) (Fig.21). The day catch was maximum in the depth range above 300m (92.59%). The study also revealed a marked increase in the catch during night from 0 – 50m to 50 – 100m, after which it shows a declining trend. Figure 22 show that the congrid leptocephali was concentrated more, especially in the night, within the 100m range with a maximum of 243 and 351 numbers in two instances. The congrid leptocephali were present to a maximum depth of 420m.

d) Horizontal variation

The analyses revealed a complete absence of congrid leptocephali in the 0 – 200m bottom depth zone. Diurnal variation studies showed that the major share of the night catch was represented by the 1000-3000m depth zone (94.93%) where as, that of the day catch was 60% by 200 – 1000m. (Fig.23)

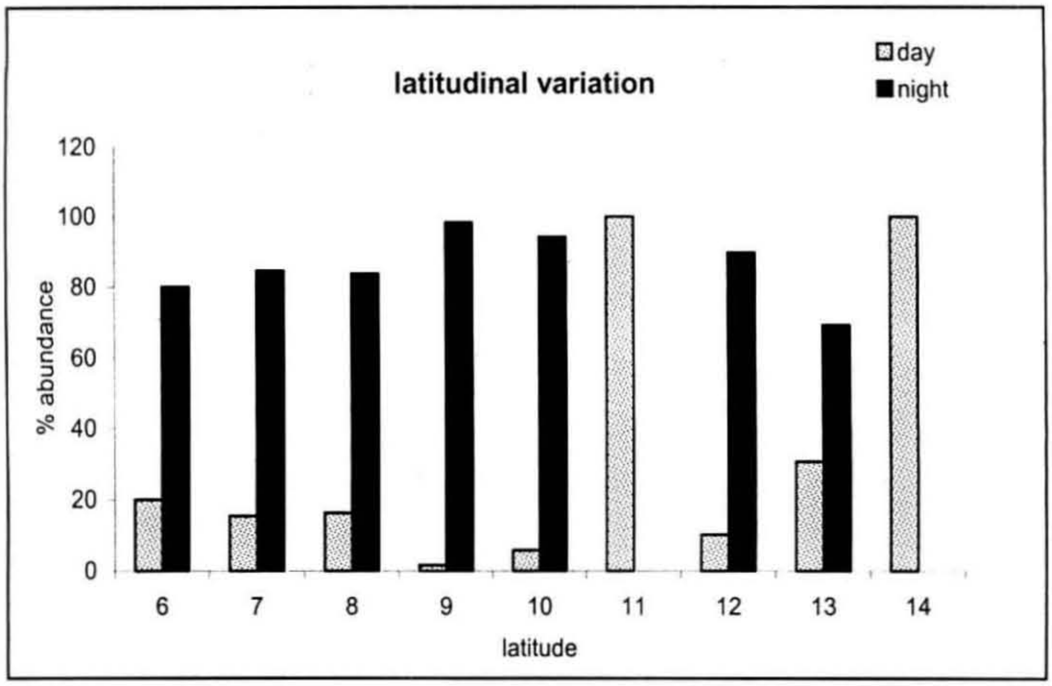


Fig.19. Congridae – latitudinal variation (day and night)

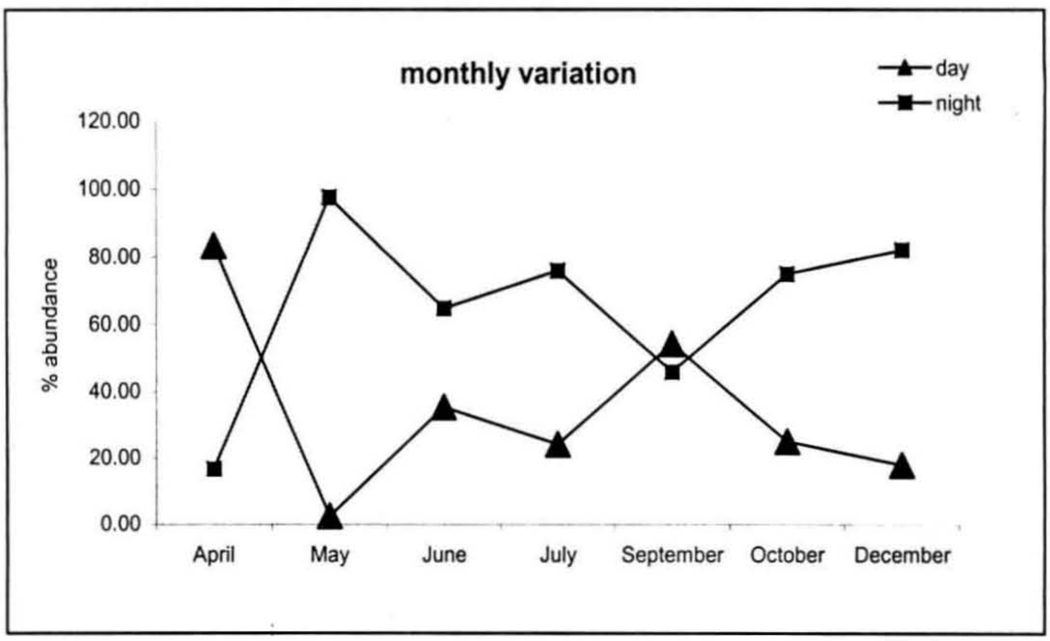


Fig.20. Congridae – Monthly variation (day and night)

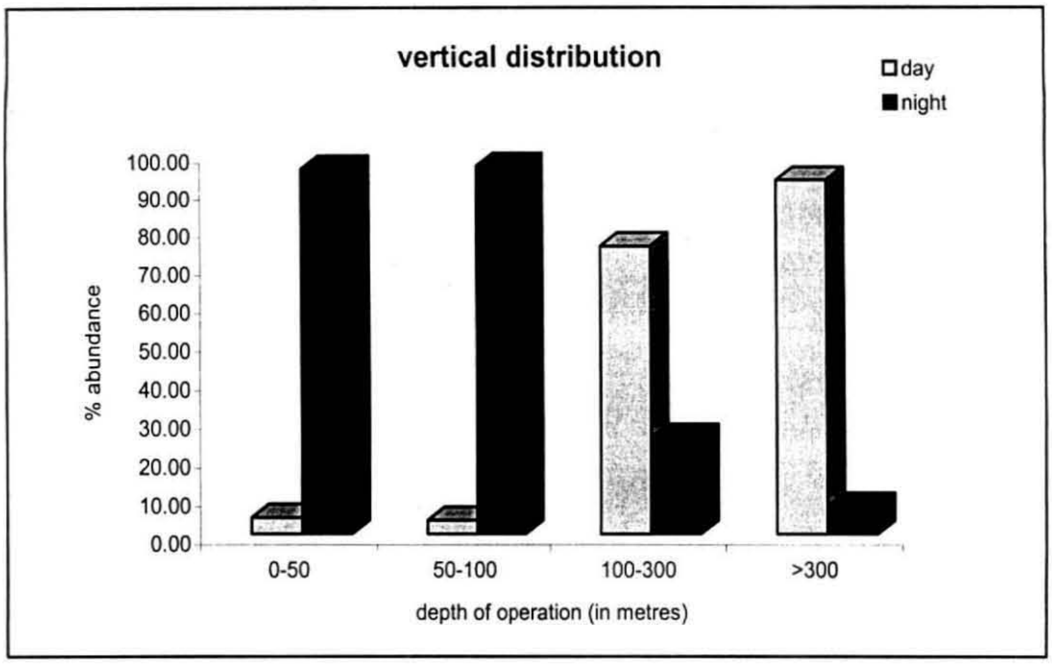


Fig.21. Congridae – Vertical distribution (day and night)

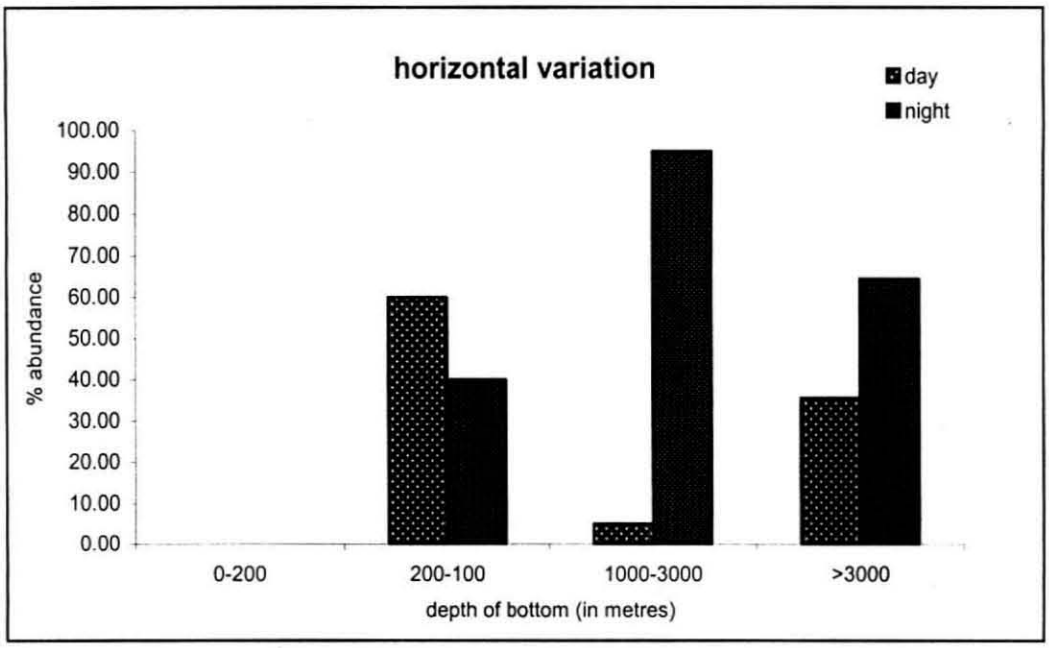


Fig.23. Congridae – Horizontal variation (day and night)

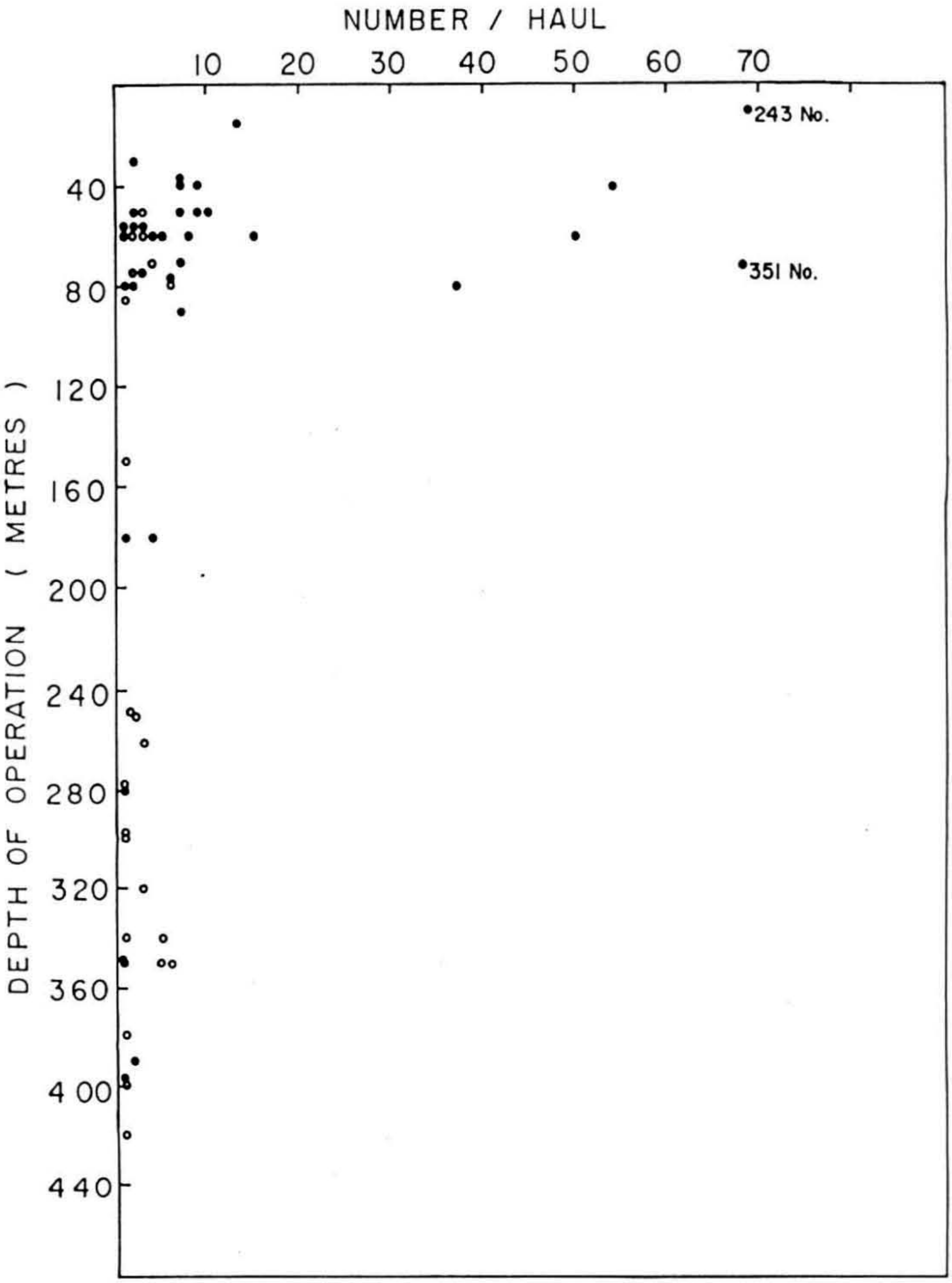


Fig: 22 Distribution (Day & Night) of Congridae (No. / haul) in the South West Coast of India

Family - Ophichthidae

Leptocephali of the family Ophichthidae represented as the second largest family in the IKMT collection, which formed 30% of the total leptocephali on the South west coast of India. The ophichthid leptocephali show a maximum aggregation off Mangalore in the 12° latitude. (Fig24)

The region wise abundance, as given in Table 10, clearly shows that the aggregation was more in the 12° latitude which contributing a major share of 78.08% of the total ophichthid catch. The percentage representation by all the other latitude were less than 10% of the total ophichthid catch in the south west coast of India.

Monthly abundance show a great degree of variation from a high of 73.66% to as low as 0.47%. The maximum abundance of ophichthid leptocephali was noticed in the month of July, contributing a share of 73.66% of the total ophichthid catch from the south west coast of India (Table 11). The study also states that the season wise abundance was more during monsoon (June-September). The catch contribution in other months was comparatively low.

Vertical abundance of the congrid leptocephali shows that the maximum contribution was from 50-100m, accounting to about 86.59% of the total, ophichthid leptocephali (Table 12). Repreşentation in other depth ranges was very low in comparison (less than 10).

Studies revealed that the abundance of ophichthid leptocephali with respect to the depth of bottom was more in the depth zone of 1000-3000m contributing 85.49% of the total ophichthid catch. (Table 13). In the other depth zones the contribution was very low.

Abundance of the family Ophichthidae during a period of 24 hours shows that the catch was more during the early hours of the day between 04 00-08 00 hours, contributing to about 76.03% of the total.

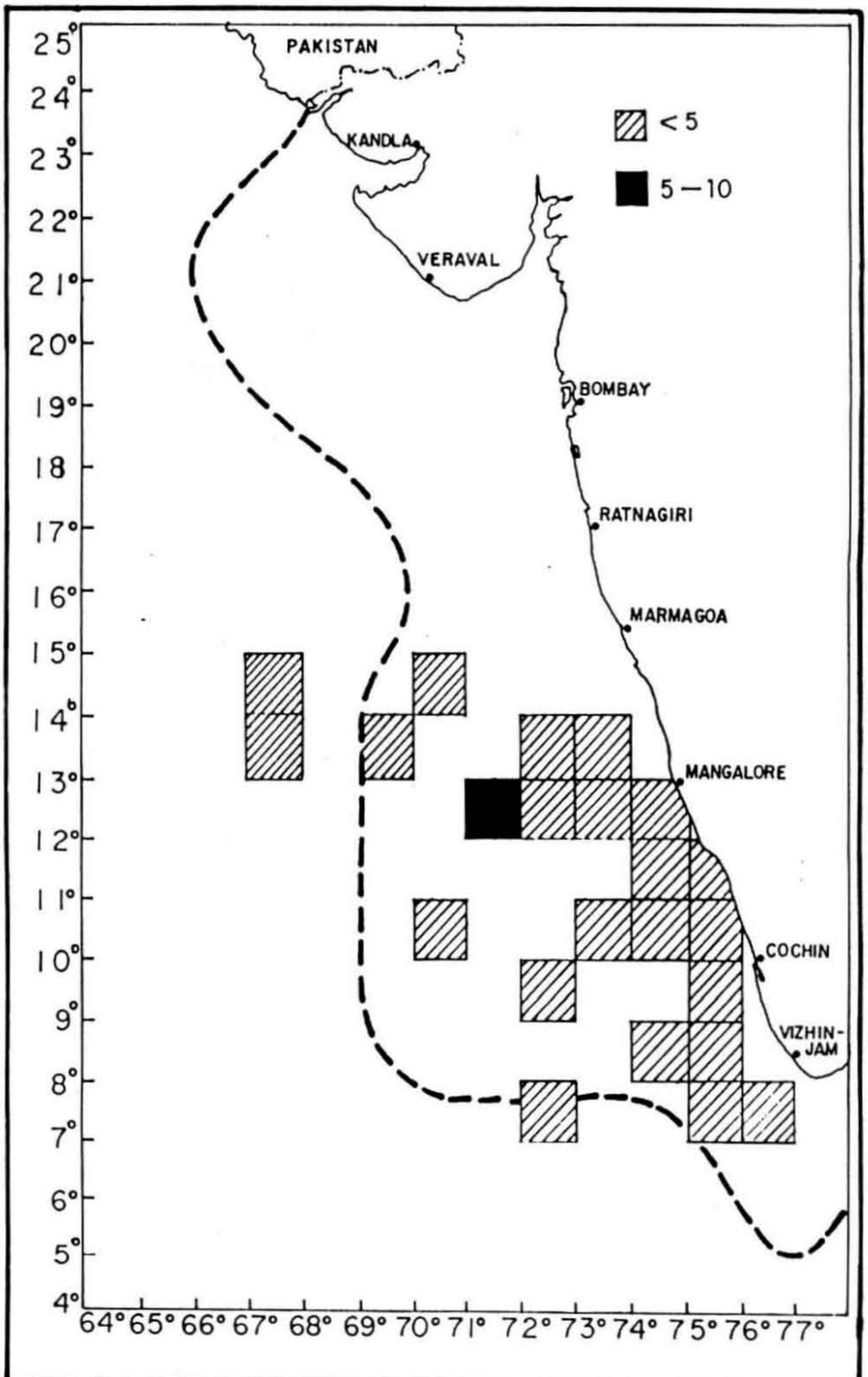


Fig: 24 Distribution and abundance of Ophichthidae (No/1000 m^3) in the South West coast of India

Table 10. Latitude wise abundance

Latitude	% Abundance
7	0.79
8	1.74
9	1.26
10	9.46
11	0.32
12	78.08
13	5.05
14	3.31

Table 11. Month wise abundance

Month	% Abundance
APRIL	2.68
MAY	4.89
JUNE	0.16
JULY	73.66
SEPTEMBER	0.47
OCTOBER	6.94
DECEMBER	11.20

Table 12. Vertical abundance

Depth of Operation (m)	% Abundance
0-50	5.52
50-100	86.59
100-300	0.95
>300	6.94

Table 13. Horizontal abundance

Depth of Bottom (m)	% Abundance
0 - 200	0.16
200 - 1000	6.94
1000 - 3000	85.49
>3000	7.41

Day-night abundance

a) Latitudinal variations

Studies on the diurnal abundance of ophichthid leptocephali revealed that the night catch was generally high through out, with a maximum representation at12° latitude (97.98%), followed by 10° and 13° latitudes with a contribution of 93.33% and 93.75%, respectively (Fig.25). The day catch was low in comparison, with the 7° latitude representing a major share of 60%.

b) Vertical distribution

Diurnal variation studies on different depths of operation revealed that 50 – 100m contributed maximum with a share of 97.81% (Fig.26). It was noted that the percentage representation of the night catch in the depth ranges of 0-50m (97.14%) and 50-100m (97.81%) were almost same with no predictable variation. The study also revealed that the aggregation of Ophichthidae was more within the depth range of 100m, especially during night with a maximum number of 452 numbers in one instance. The leptocephali were available to a maximum depth of 750m (Fig.27). The percentage contribution of day catch was more on 100-300m depth range (83.33%).

c) Horizontal distribution

The studies revealed that the maximum representation in the night catch was in the depth zone of 1000 – 3000m (96.86%), followed by 200-1000m with a share of 86.36%. The percentage representation of day catch was maximum in the depth zone above 3000m (44.68%) (Fig28).

d) Monthly abundance

It was noted that the month of July contributed maximum of the night catch with a share of 98.07% and October for day (43.18%) (Fig.29). The studies also show the season wise abundance of the ophichthid leptocephali during the monsoon.

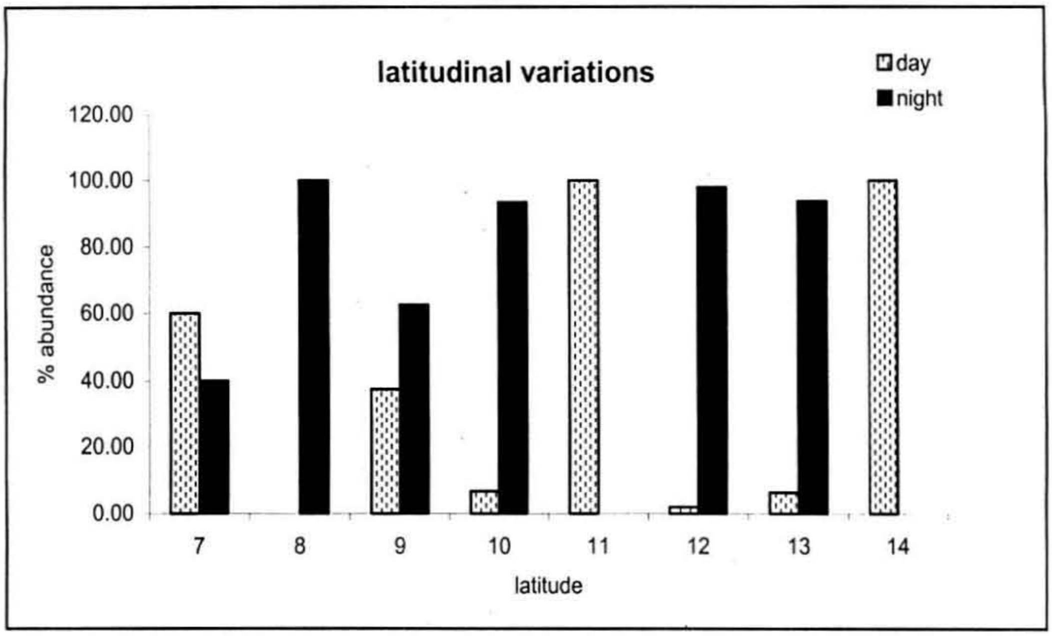


Fig.25. Ophichthidae – Latitudinal variations (day and night)

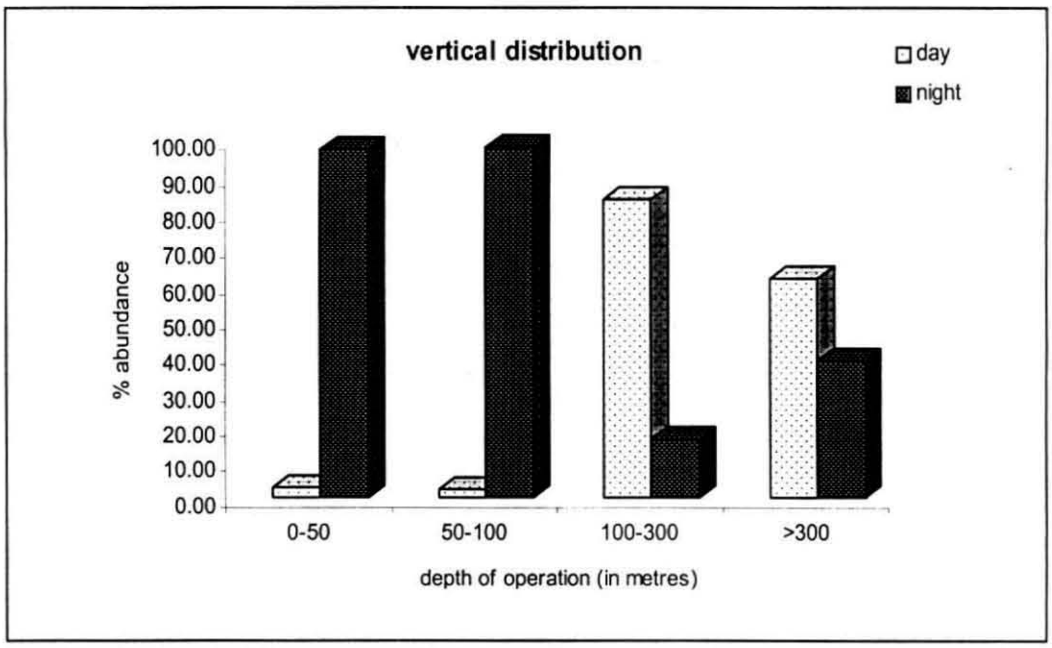


Fig.26.Ophichthidae – Vertical distribution (day and night)

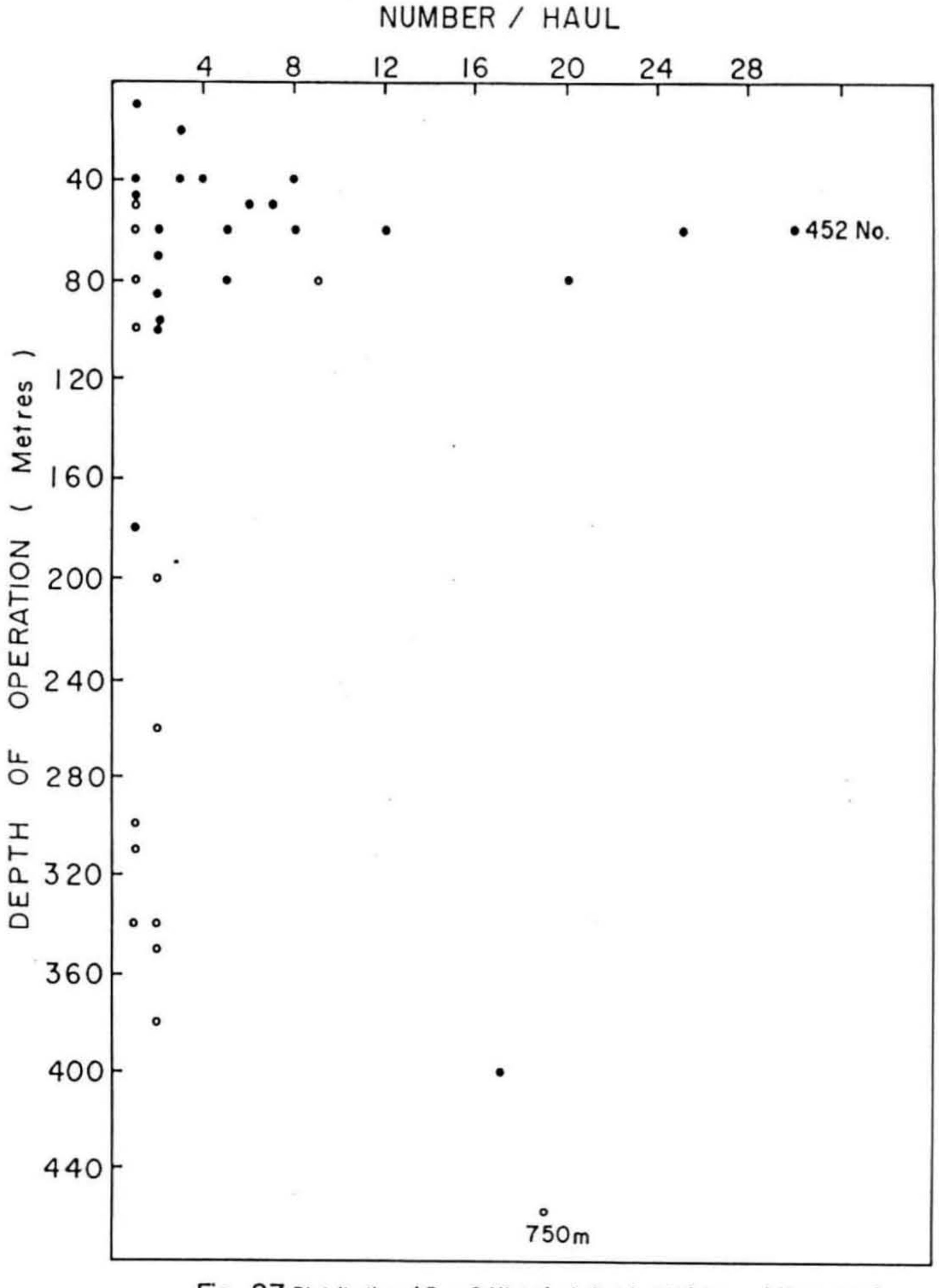


Fig: 27 Distribution (Day & Night) of Ophichthidae (No./haul)
in the South West Coast of India

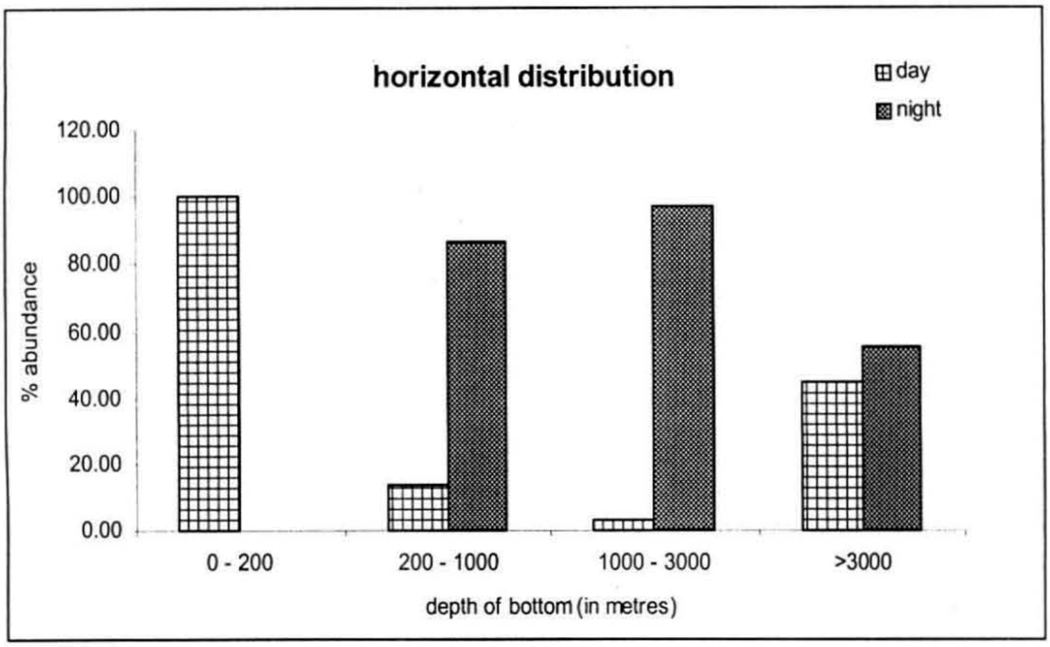


Fig.28. Ophichthidae – Horizontal distribution (day and night)

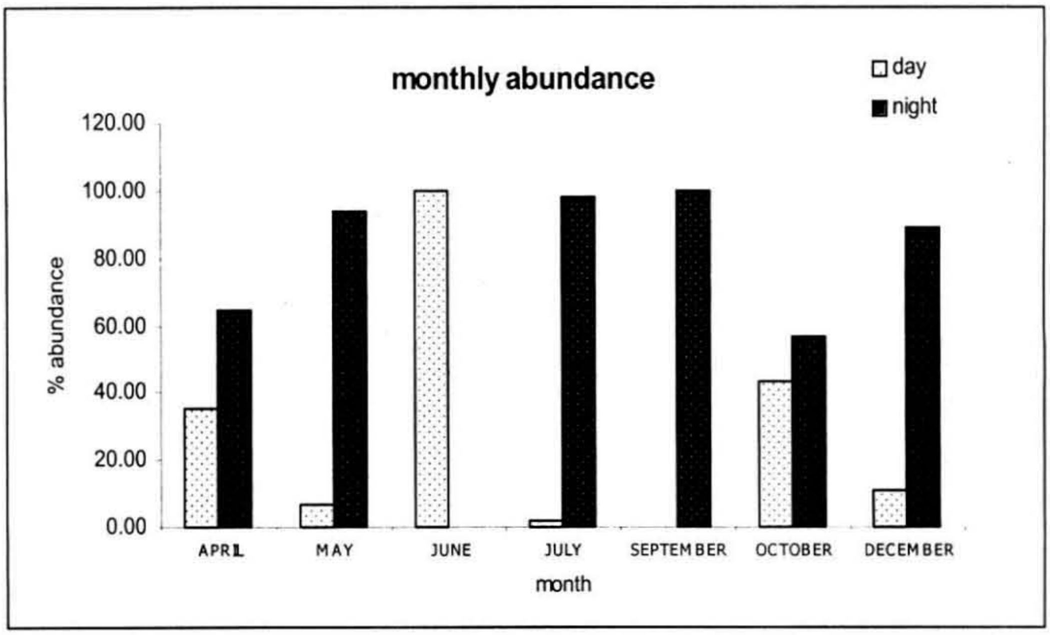


Fig.29. Ophichthidae – Monthly abundance (day and night)

Family - Muraenidae

Though the third largest family in the IKMT collection the representation of Muraenid leptocephali was very less in comparison with Congridae and Ophichthidae, which formed only 2.65% of the total south west coast leptocephali. Even though the numerical abundance was less, the leptocephali were evenly distributed with no dense pocket of abundance. In general, the distribution and abundance was slightly prominent in the area between 8° and 11° latitudes. (Fig.30)

Latitude wise abundance shows not much variation but with a slightly high abundance in the 10° latitude constituting to about 25.93% of the total muraenid catch (Table14). In other latitudes the percentage representation varied from a low of 1.85% to 16.67%.

Vertical abundance of the muraenid leptocephali was high in the depth range of 50-100m, accounting to about 61.11% of the total. The contribution in other depth ranges was low in comparison (less than 20%). The lowest percentage abundance was from the depth above 300m (3.70%) (Table 15)

The muraenid leptocephali were totally absent in the 0-200m depth (bottom) zone. In the other depth zones, 1000-3000m region contributed the highest with a 50% representation of the total muraenid leptocephali, followed by 200-1000m range (42.59%) (Table 16). The percentage contribution of the region above 3000m was very poor, accounting to only 7.41%.

Sample analyses revealed that the monthly abundance of the muraenid leptocephali were more in December which contributing to about 53.70% of the total. The month of May contributed to about 18.52%, where as in rest of the months the percentage contribution was less than 10. (Table 17)

Diurnal variation shows a maximum abundance during the early hours of the day between 04 00 – 08 00 hours, contributing 33.33% of the total muraenid leptocephali in the southwest coast of India.

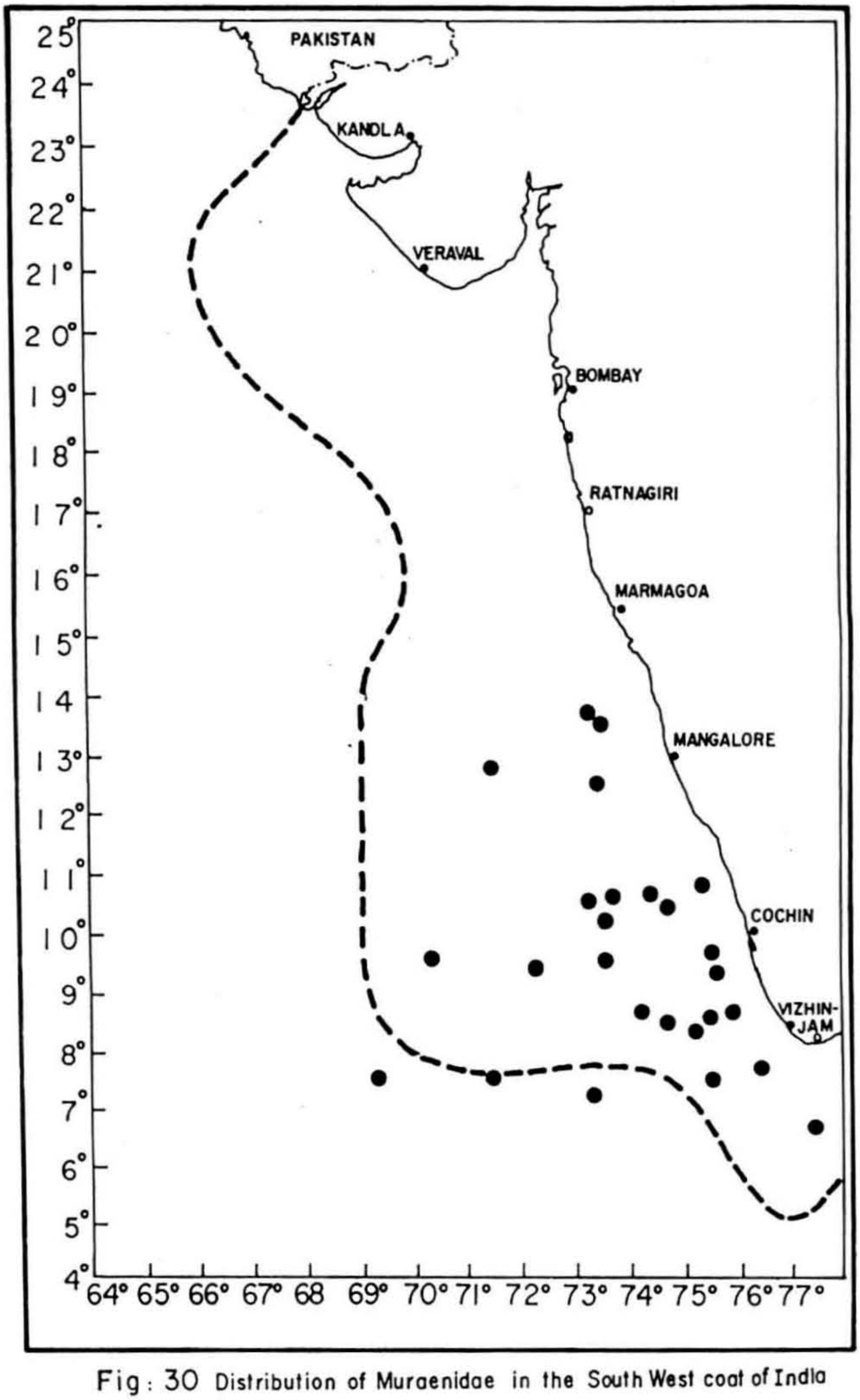


Fig : 30 Distribution of Muraenidae in the South West coat of India

Table 14. Latitudinal abundance

Latitude	% Abundance
6	1.85
7	11.11
8	12.96
9	16.67
10	25.93
12	14.81
13	16.67

Table 15. Vertical abundance

Depth of Operation (m)	% Abundance
0 - 50	16.67
50 - 100	61.11
100 - 300	18.52
>300	3.70

Table 16. Horizontal abundance

Depth of Bottom (m)	% Abundance
0 - 200	0.00
200 - 1000	42.59
1000 - 3000	50.00
>3000	7.41

Table 17. Month wise abundance

Month	% Abundance
APRIL	5.56
MAY	18.52
JUNE	3.70
JULY	1.85
SEPTEMBER	7.41
OCTOBER	9.26
DECEMBER	53.70

Day-night variation

a) Latitudinal abundance

The general abundance of the muraenid leptocephali was low, though it formed as the third largest family in the IKMT collection. Latitude wise day-night abundance shows that the percentage contribution to the night catch was high in the 10° latitude (85.71%) and a low contribution of 11.11% in the 9° latitude. The daytime contribution was high in the 9° latitude with a share of 88.89%. (Fig.31)

b) Vertical abundance

The operational depth wise studies shows that during the muraenid leptocephali concentrated more in the 50-100m depth range with a percentage representation of 87.88 (Fig 32). The daytime catch was maximum in the 0-50m depth range (33.33%). The studies further revealed that generally the muraenid leptocephali aggregated with in the depth range of 100m, especially in the night and also making its presence up to a depth of 420m (Fig.33).

c) Horizontal abundance

There was a total absence of muraenid leptocephali in the 0-200m depth zone. Studies also revealed that the percentage contribution to the night catch was high in the depth zone of 1000-3000m (77.78%), where as for the daytime, it was the depth zone above 3000m with 75% (Fig.34).

d) Monthly abundance

Monthly abundance of the muraenid leptocephali during night revealed that the percentage representation was high during the month of December (79.31%), and a low of 33.3% in April. The daytime catch was high in the month of April (66.67%). (Fig. 35)

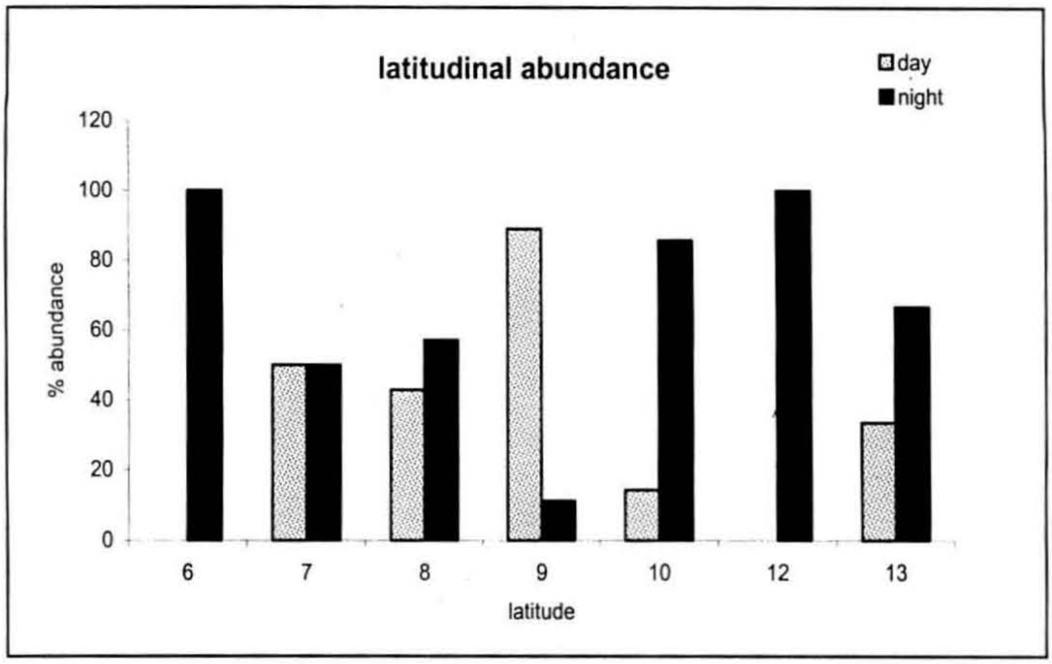


Fig.31. Muraenidae – Latitudinal abundance (day and night)

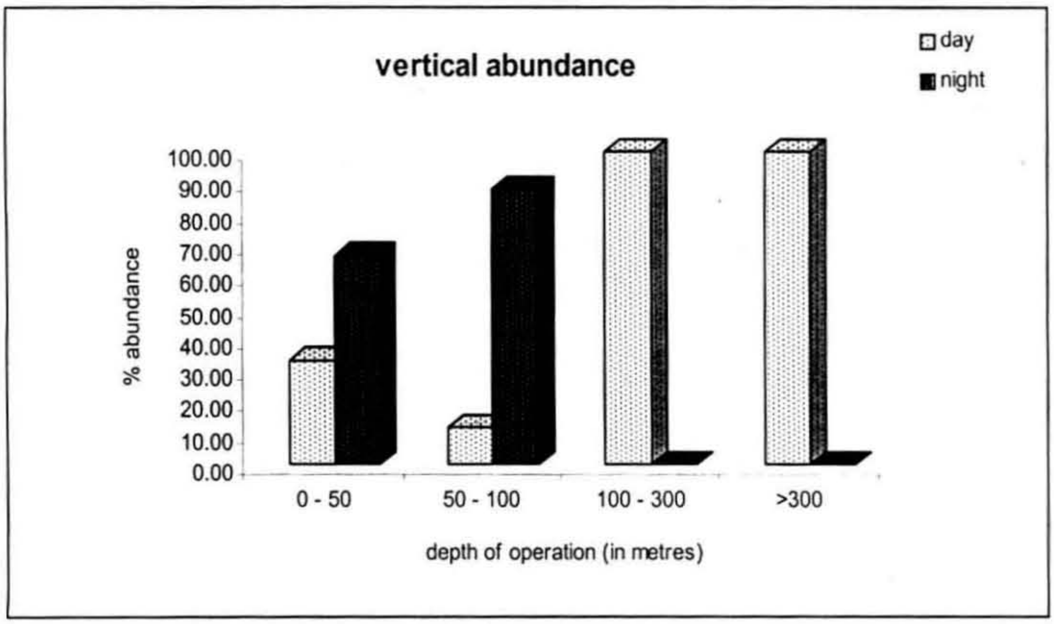


Fig.32. Muraenidae-vertical abundance (day and night)

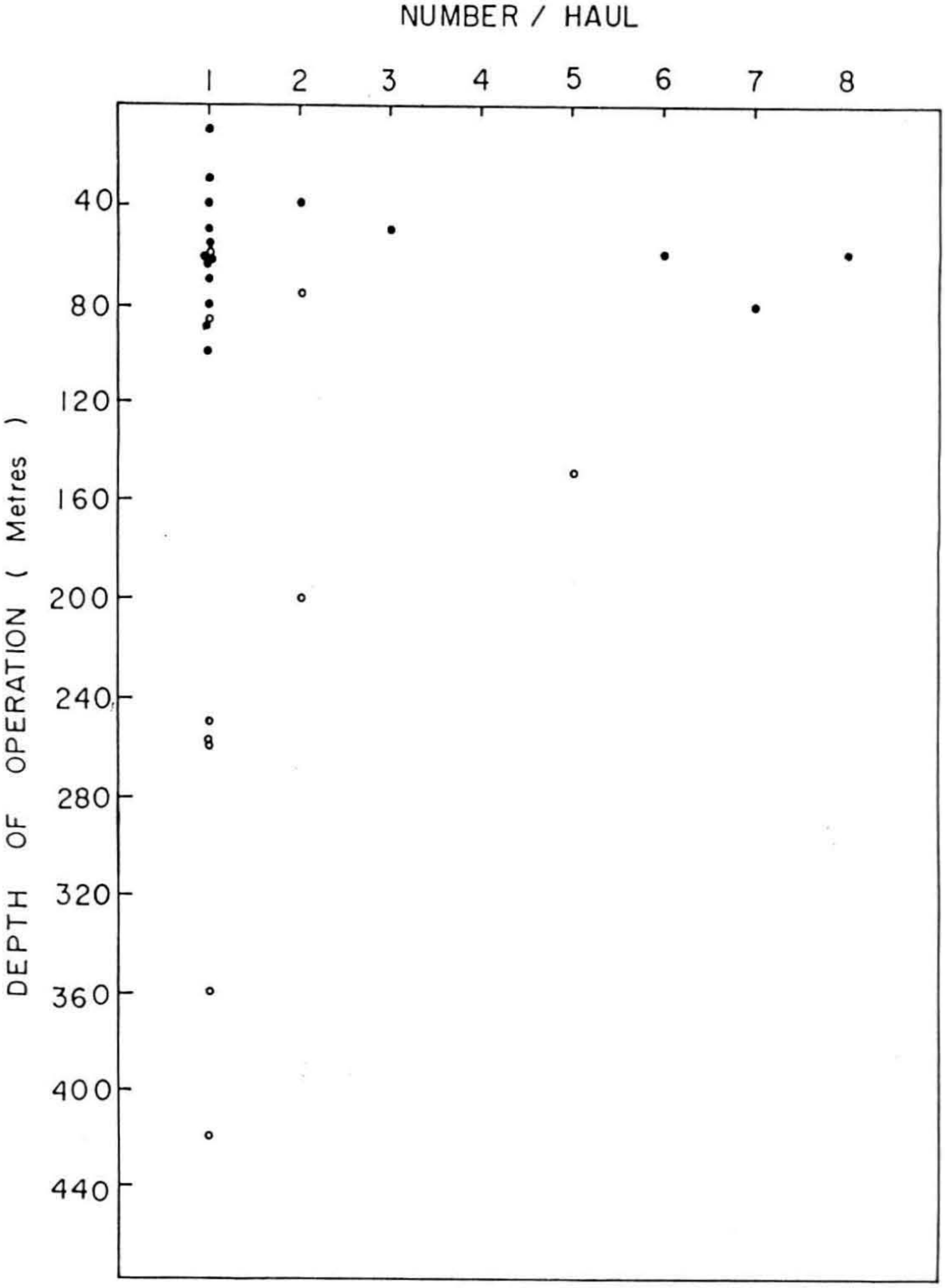


Fig: 33 Distribution (Day & Night) of Muraenidae (No./haul)
in the South West Coast of India

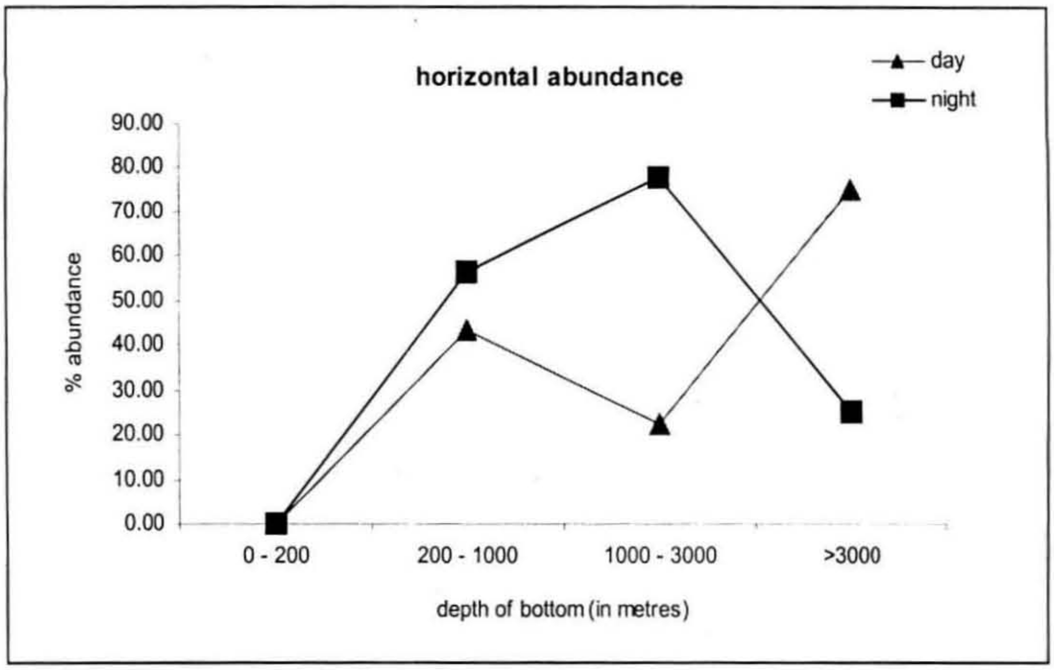


Fig.34. Muraenidae-horizontal abundance (day and night)

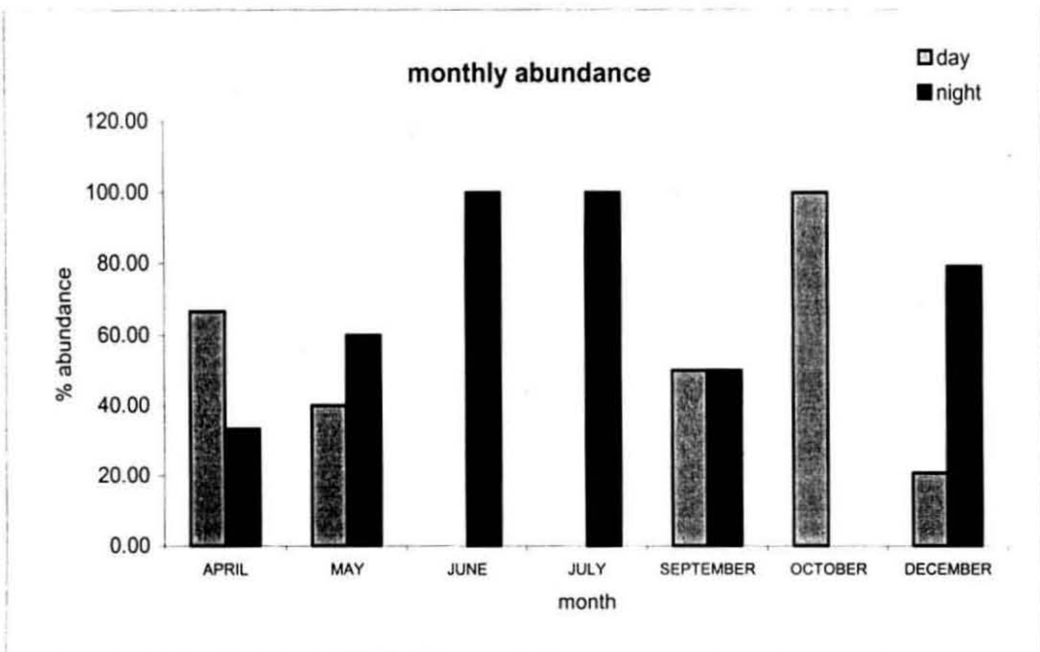


Fig.35. Muraenidae-monthly abundance (day and night)

Family – Nemichthyidae and Synaphobranchidae

The leptocephali of two families viz. Nemichthyidae and Synaphobranchidae formed only a negligible percentage (1.5% and 0.83%, respectively) in the southwest coast of India. They were present only in 12 and11 stations respectively, in small numbers. The distribution of the two families is given in Fig 36.

Latitudinal distribution

The leptocephali of both the families show a scattered distribution along the different latitudes. Maximum number per haul for Nemichthyidae was seven and Synaphobranchidae four in the 13° and 10° latitudes, respectively. The latitude wise distributions of the two families are given in Table18 and 19.

Vertical distribution

Leptocephali of both the families were present to a maximum depth of 380m (Nemichthyidae) and 400m (Synaphobranchidae). (Fig.37 and 38;Table 20 and 21). Nemichthyid leptocephali were more abundant in the depth range of 370m (7 numbers) where as that of Synaphobranchidae in the 120m depth range (4 numbers).

Horizontal distribution

The nemichthyid and synaphobranchid leptocephali were found to aggregate in deeper waters, with a maximum depth of abundance of 4633m and a minimum of 300m and 531m for Nemichthyidae and Synaphobranchidae, respectively. (Table 22 and 23)

Due to the scarcity of samples, the analyses of data for other parameters were not possible.

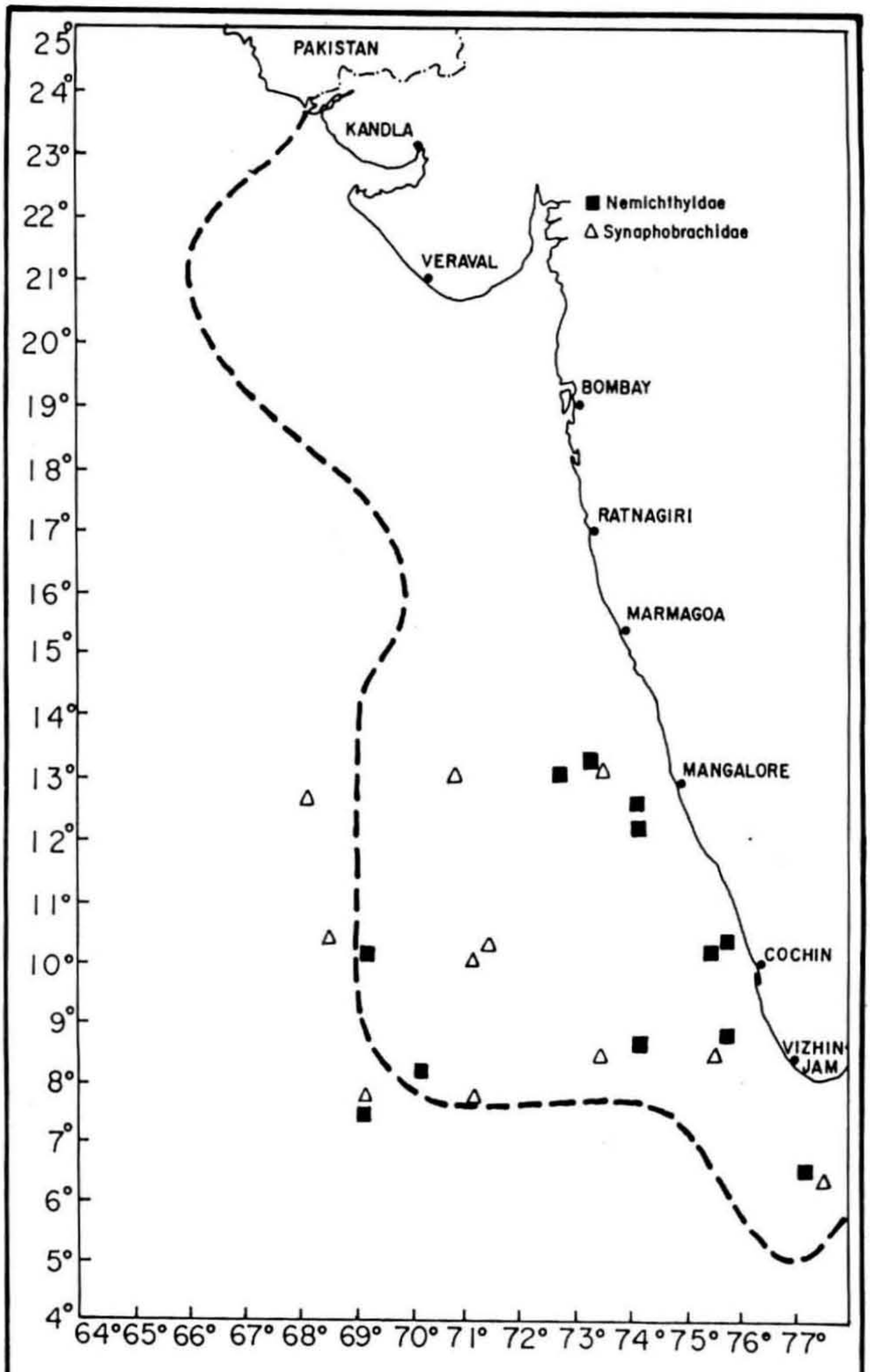


Fig. 36: Distribution of Nemichthyidae and Synaphobranchidae in the South-West coast of India

Table18. Nemichthyidae

Latitude (°N)	Longitude (°E)	No./haul
6° 38	77° 31	2
7° 59	69° 02	2
8° 40	75° 36	1
8° 00	74° 04	1
8° 00	70° 02	1
10° 00	69° 00	1
10° 16	75° 29	6
10° 21	75° 34	3
12° 34	74° 06	3
12° 28	74° 09	1
13° 01	72° 57	3
13° 09	73° 40	7

Table 19. Synaphobranchidae

Latitude (°N)	Longitude (°E)	No./haul
6° 38	77° 31	1
7° 59	69° 02	1
7° 52	71° 12	1
8° 30	75° 30	2
8° 29	73° 32	1
10° 25	71° 31	1
10° 00	71° 00	1
10° 31	68° 32	4
12° 54	68° 04	1
13° 00	70° 57	2
13° 09	73° 40	2

Table 20. Nemichthyidae

Depth of Operation (m)	No./haul
30 - 40	2
40 - 50	1
50	6
60	1
90	1
100	3
180	1
250 - 300	2
300	3
340	3
370	7
380	1

Table 21. Synaphobranchidae

Depth of Operation (m)	No./haul
60 - 80	1
75	2
120	4
250	1
250 - 300	1
280	1
320	2
350	1
370	2
390 - 400	1
400	1

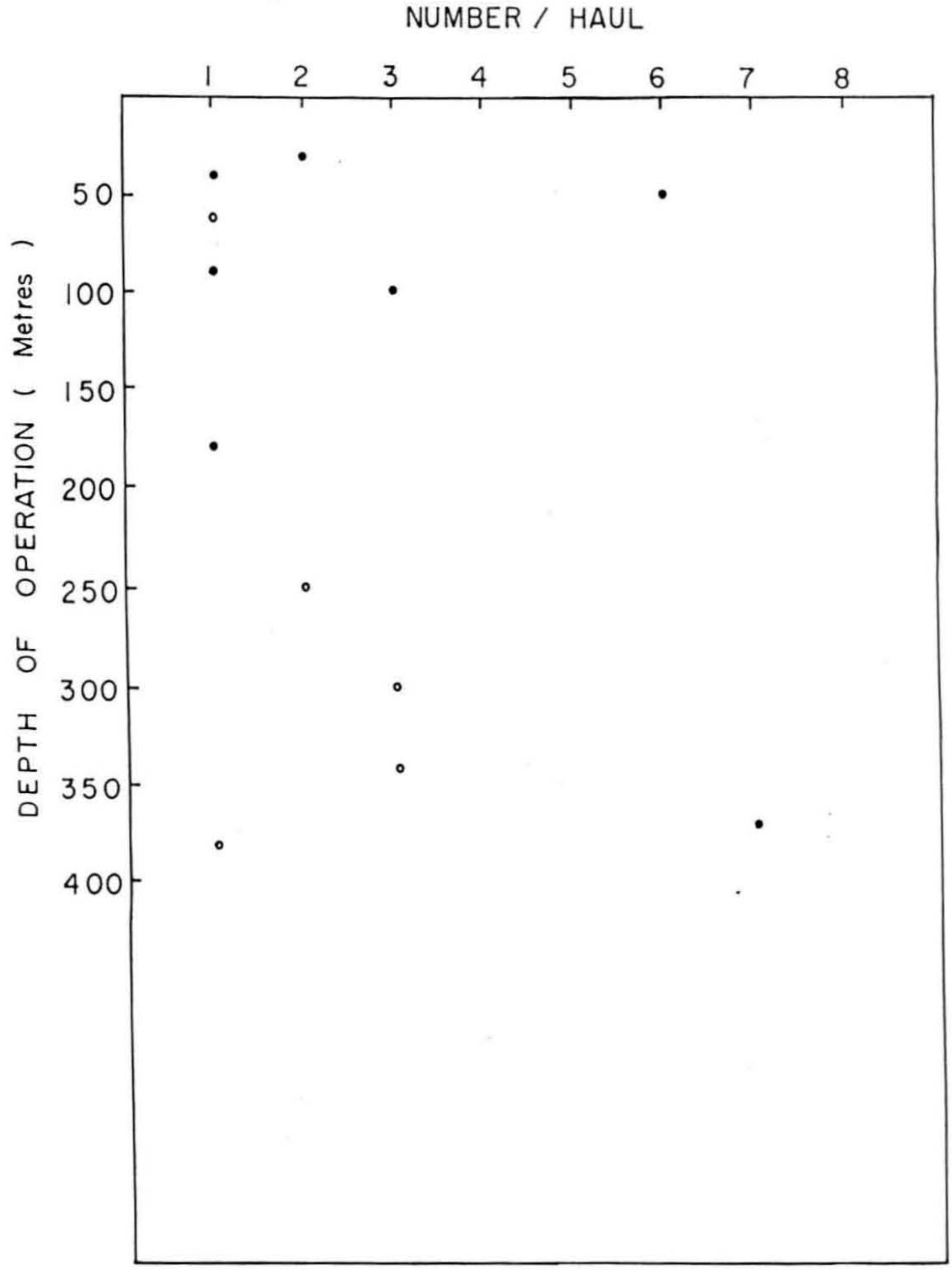


Fig: 37 Distribution (Day & Night) of Nemichthyidae (No./haul) in the South West Coast of India

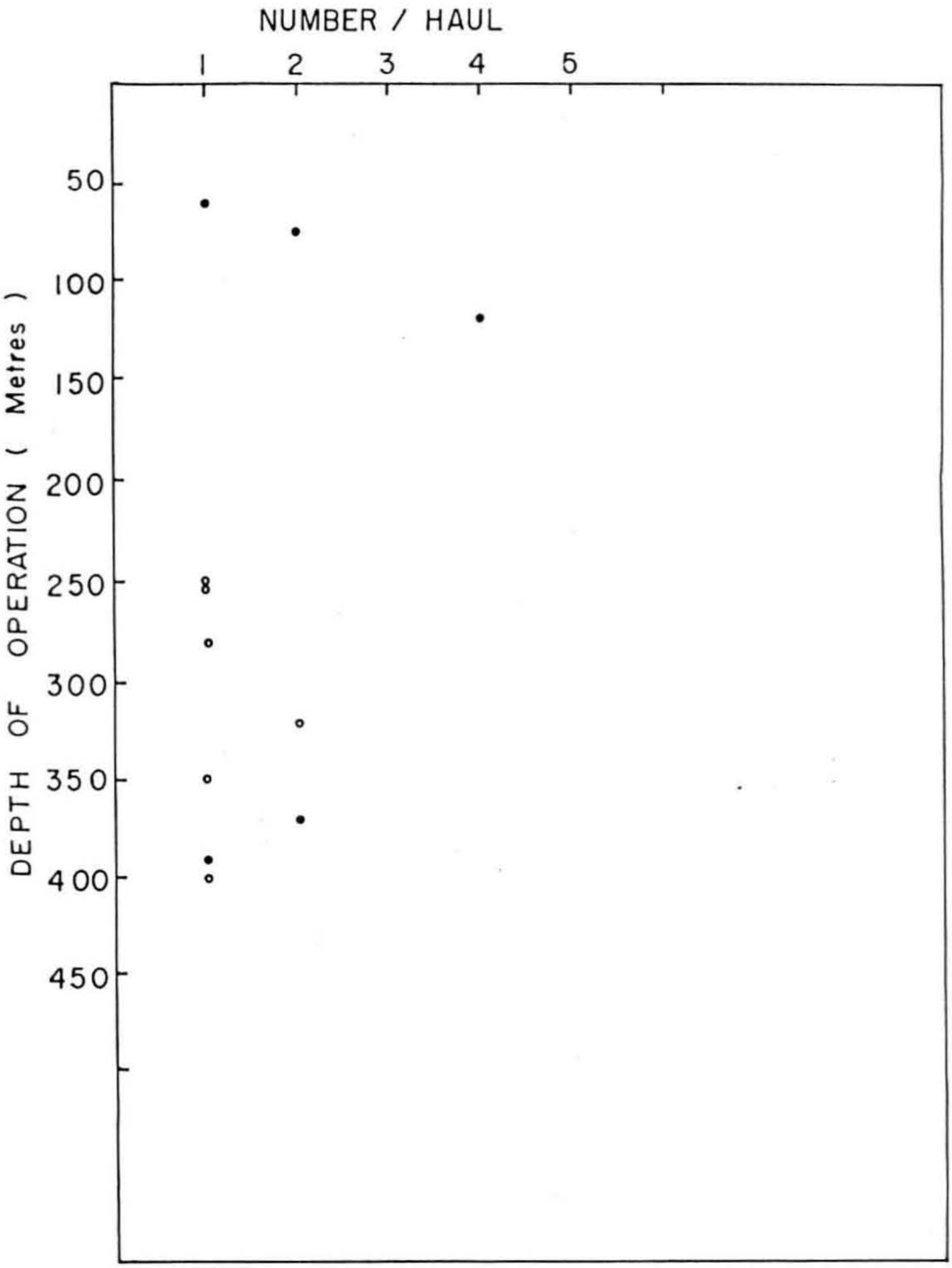


Fig : 38 Distribution (day & night) of Synaphobranchidae (No. / haul) in the South West Coast of India

Table 22. Nemichthyidae

Depth of Bottom (m)	No./haul
300	1
395	1
500	3
531	7
792	3
1089	6
1937	3
2415	2
2770	1
4181	1
4514	1
4633	2

Table 23. Synaphobranchidae

Depth of Bottom (m)	No./haul
531	2
1409	2
2039	1
2310	1
2405	2
2415	1
3351.3	1
3646	1
4186	1
4452	4
4633	1

Biomass estimation of Leptocephali

West Coast

To understand the resource potential, the estimation of total biomass was carried out. The biomass was calculated in tones for every 1° square. The study revealed that leptocephali had a fairly good abundance along the west coast of India. It was present on all depth ranges – vertically (0-50m, 50-100m, 100-300m, >300m) or horizontally (0-200m, 200-1000m, 1000-3000m, >3000m) and on every latitude from 6°N to 21°N. The total biomass on the west coast was 76227.87t with an average of 515.05t (148 stations). Maximum biomass was recorded in the 19° latitude, off Bombay (6481.88t). North west coast accounted for the major share (54817.65t) of total leptocephali biomass, which formed 71%. The major stations where the leptocephali biomass was more than 1000t are given in Table 24.

Geographical variation in Biomass

The abundance of leptocephali (in tones) was more or less even through out the west coast with a single high density pocket (>3000t) in the northwest region (19°N – 68°E). The least density areas (<100t) were more concentrated towards the south, particularly in the near shore waters of Mangalore. In comparison with the north west coast there was only one dense area of abundance (1000-3000t) in the south west coast, off Mangalore. In general, the abundance was more prominent in the north west coast. (Fig.39)

Latitudinal abundance

The leptocephali were found abundant in the area above 15° latitude with a dense area of abundance (>3000t) in the 19° latitude (off Bombay). Latitude wise average biomass value ranged from a high of 1973.14t (19° latitude) to a low of 25.82t in the 11° latitude (Fig.40).

Table24. Major areas with higher biomass (>1000t)

Station No.	Area of operation	Latitude	Longitude	Time (Hrs) From	To	DSL thickness (m)	Depth of operation (m)	Depth of bottom (m)	No. of Leptocephali	Biomass 1^0Square (in Tones)
17	SW	9^0 29	72^0 30	20 50	21 40	10	70	1810	373	1660.05
101	NW	18^0 07	64^0 35	20 00	20 30	30	30-145	1603	279	3725.84
103	NW	18^0 23	70^0 10	11 35	12 05	40	40-80	1345	140	2493.79
104	NW	18^0 27	70^0 30	17 10	17 40	60	40-80	332	184	4913.36
116	SW	12^0 30	71^0 29	05 25	05 55	10	60-70	1584	509	2266.18
138	NW	15^0 19	72^0 52	21 44	22 15	20	15-35	229	140	1246.9
155	NW	18^0 35	70^0 17	22 30	23 00	50	35-45	764	52	1162.78
158	NW	19^0 33	69^0 20	23 35	00 05	25	35	1182	215	2393.6
495	NW	16^0 59	68^0 00	17 30	18 00	110	190	3539	31	1523.98
496	NW	17^0 00	69^0 00	04 45	05 15	35	65	2572	72	1121.34
497	NW	17^0 00	70^0 00	16 10	16 40	40	320	3476	189	3364.64
499	NW	16^0 59	71^0 51	17 25	17 55	10	185	227	242	1077.43
503	NW	18^0 59	70^0 00	02 30	03 00	25	50	254	331	3686.26
504	NW	19^0 00	68^0 58	11 40	12 10	80	320	2809	182	6481.88
508	NW	21^0 00	66^0 59	22 00	22 30	120	35	2382	20	1068.77
697	SW	8^0 00	75^0 00	23 00	00 00	100	40	2749	26	1162.78
704	SW	10^0 00	71^0 00	17 30	18 00	250	280	3646	20	2226.6
773 d	SW	12^0 57	73^0 53	03 50	04 20	60	80	419	39	1039.08
795	NW	20^0 55	66^0 55	20 30	21 00	80	40	2440	31	1108.35
794	NW	21^0 00	67^0 58	17 10	17 40	160	280-300	2665	17	1207.31
786	NW	16^0 58	69^0 59	11 35	12 05	100	340-400	3485	30	1335.96

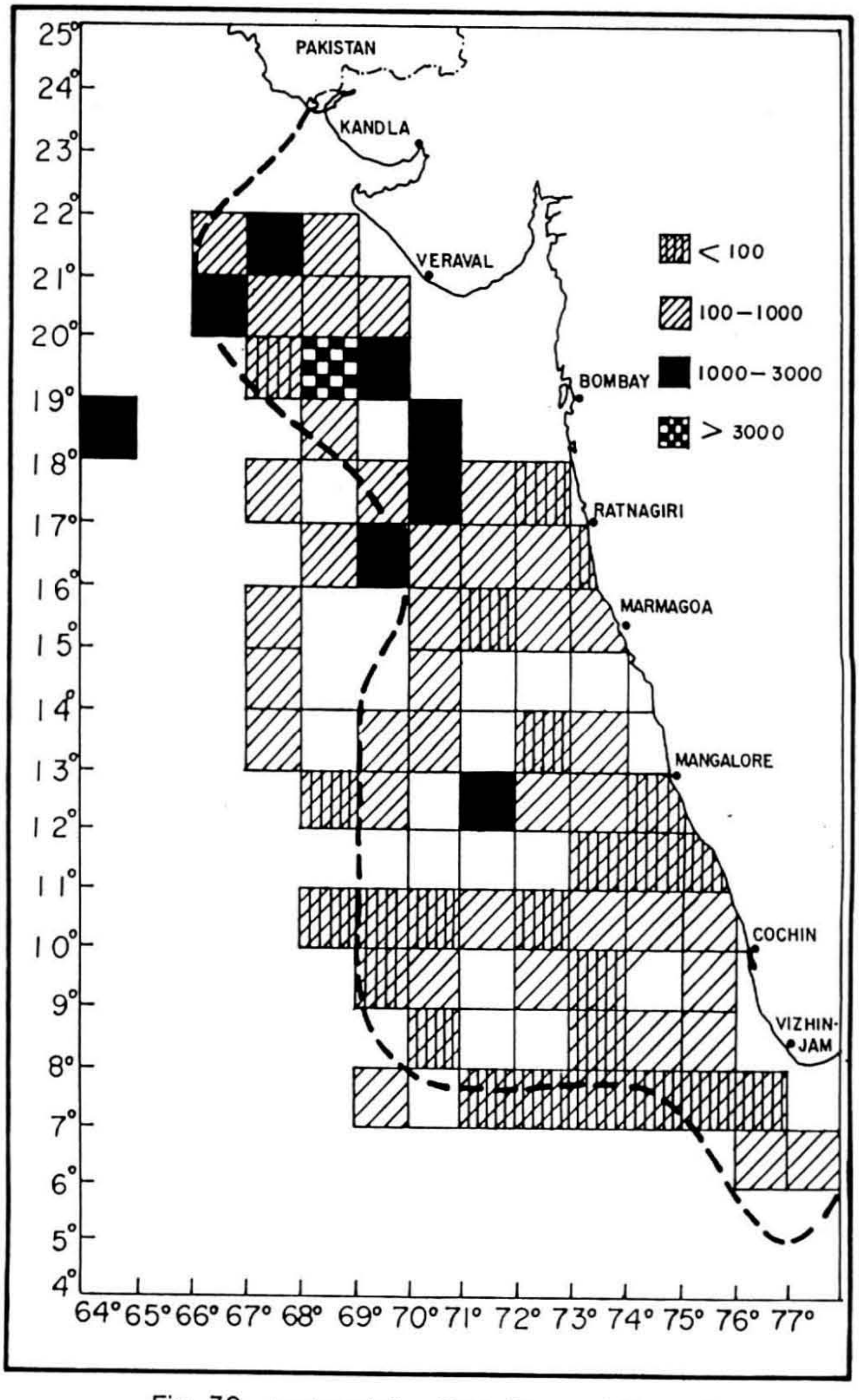


Fig. 39 Leptocephali – Total Biomass (Tonnes) in the West-coast of India

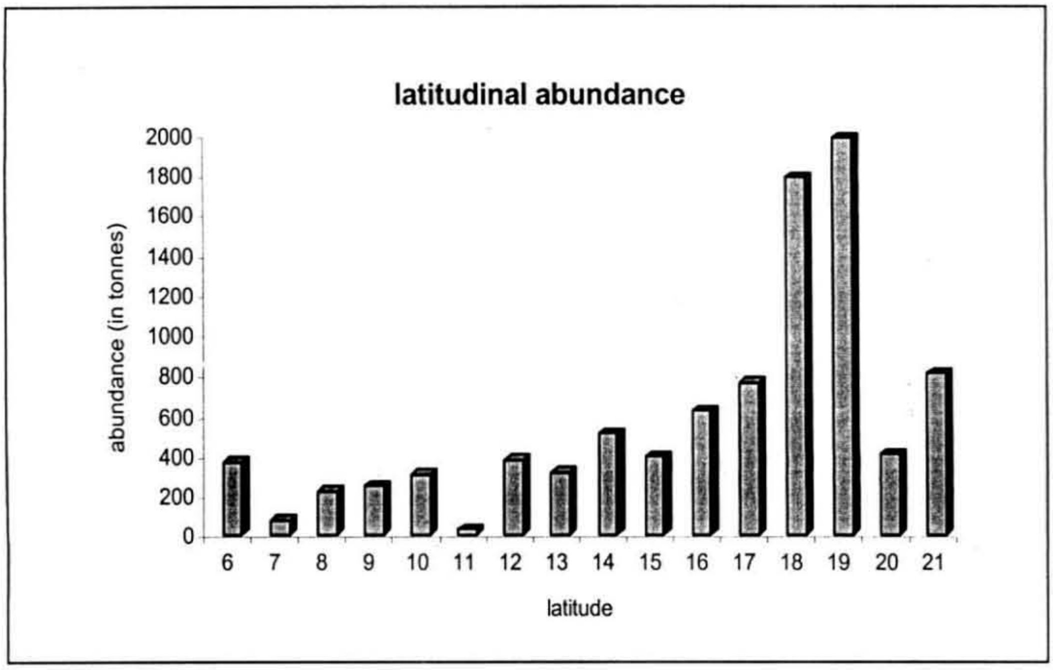


Fig.40. Latitudinal abundance of Leptocephali

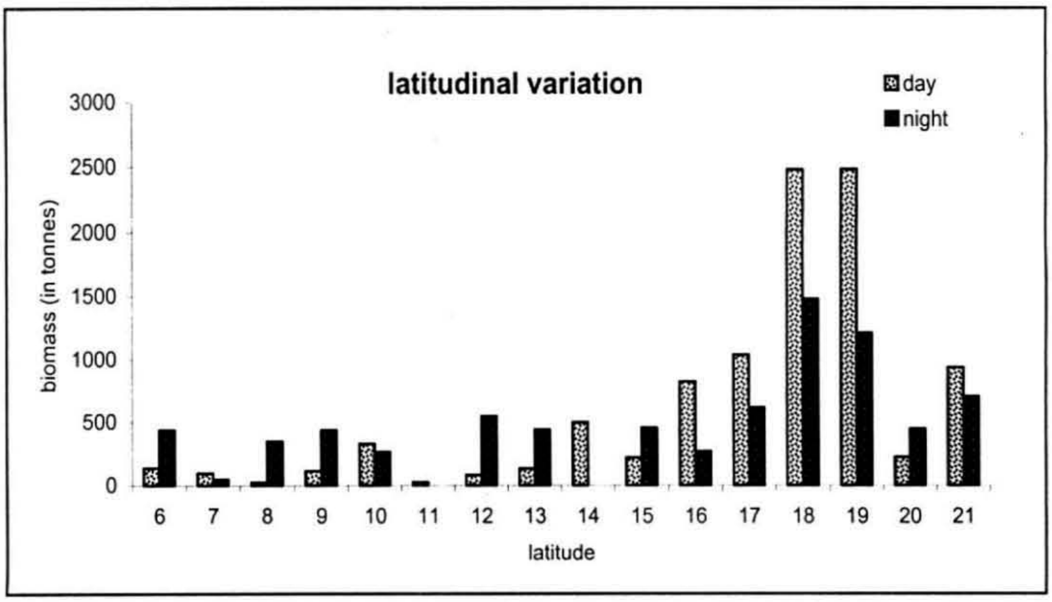


Fig.41. Latitudinal variation (day and night) in biomass of leptocephali

Day - night variations

The analyses revealed that the night biomass was more in comparison, constituting to about 55.96% of the total biomass where as, the day was 44.04%.

a) Latitudinal variation

The latitude wise estimated biomass (average) during day and night is presented in Fig.41. It shows a variation of 21.96t to a maximum of 2481.01t. The night biomass was high in the 18° latitude (1480.33t) where as that of day at 19° latitude 2481.01t.

b) Monthly variations

Monthly variations in the biomass showed a maximum in the month of March with 1166.49t during night and 2563.81t during day. In general, the biomass (average) varied from a low of 69.27t to maximum of 1726.7t through the seasons. (Fig.42)

c) Vertical abundance

Analyses revealed that the biomass (average) was maximum in the depth range of 0-50m during day (849.32t) and night (649.93t) and also in total (726.44t) (Fig.43). The minimum nighttime biomass was recorded in the 100-300m range (113.98t) where as that of the day (56.85t) in the 50-100m depth range.

d) Horizontal abundance

Bottom depth wise studies on the biomass revealed that the over all biomass was maximum in the depth zone above 3000m where as the minimum was at 0-200m depth zone. Diurnal variations show that nighttime biomass was maximum in the 1000-3000m depth zone (600.19t) and that of day (767.68t) in the zone above 3000m. (Fig.44)

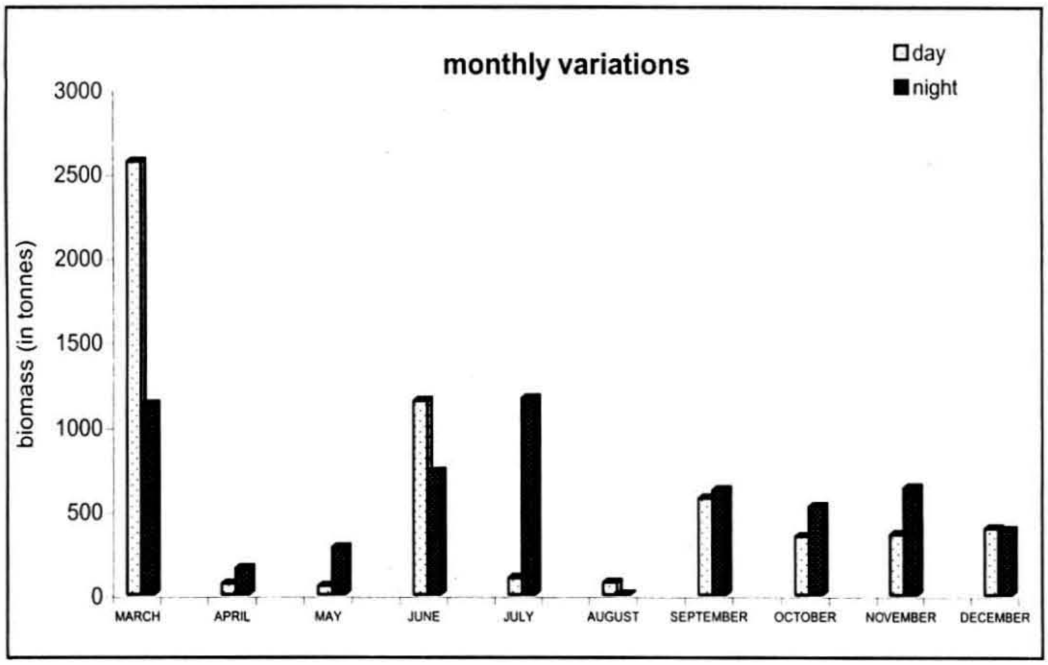


Fig.42. Monthly variations in biomass (day and night)

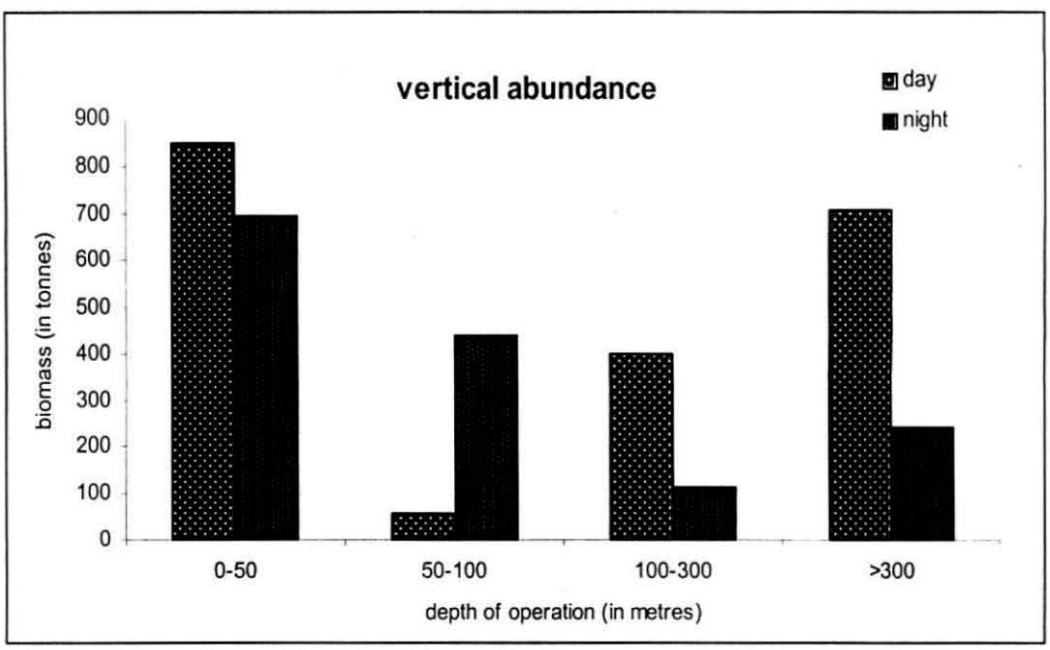


Fig.43. Vertical abundance of Leptocephali (day and night)

e) Diurnal variation

The biomass (average) leptocephali was maximum (1797.77t) during the early hours of the day between 00 00 – 04 00 hours where as the minimum was between 12 00 – 16 00 hours (205.15t). (Fig.45)

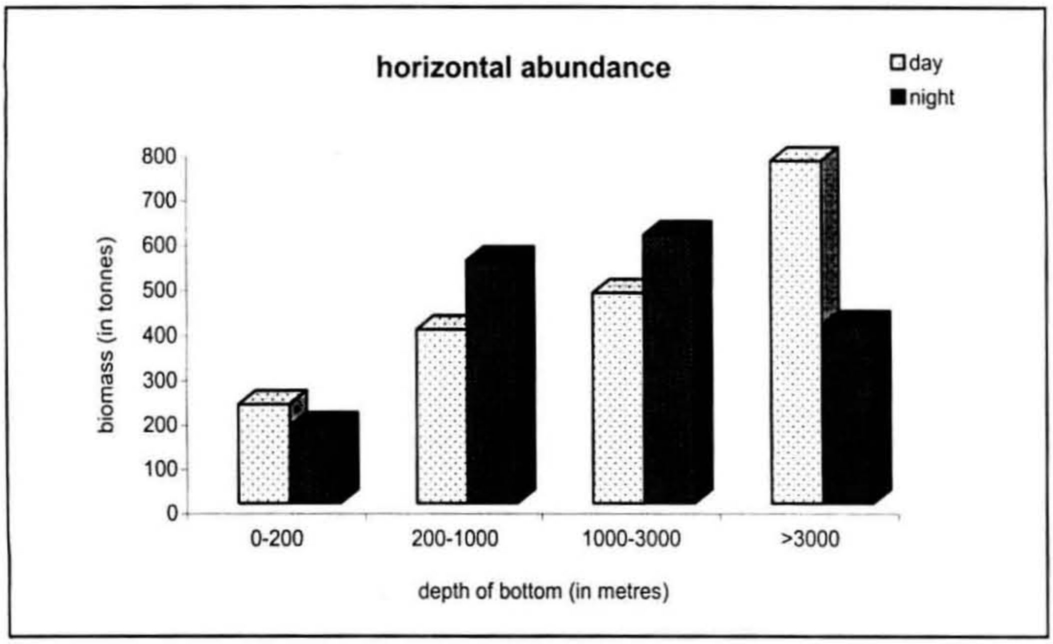


Fig.44. Horizontal abundance (day and night) of Leptocephali

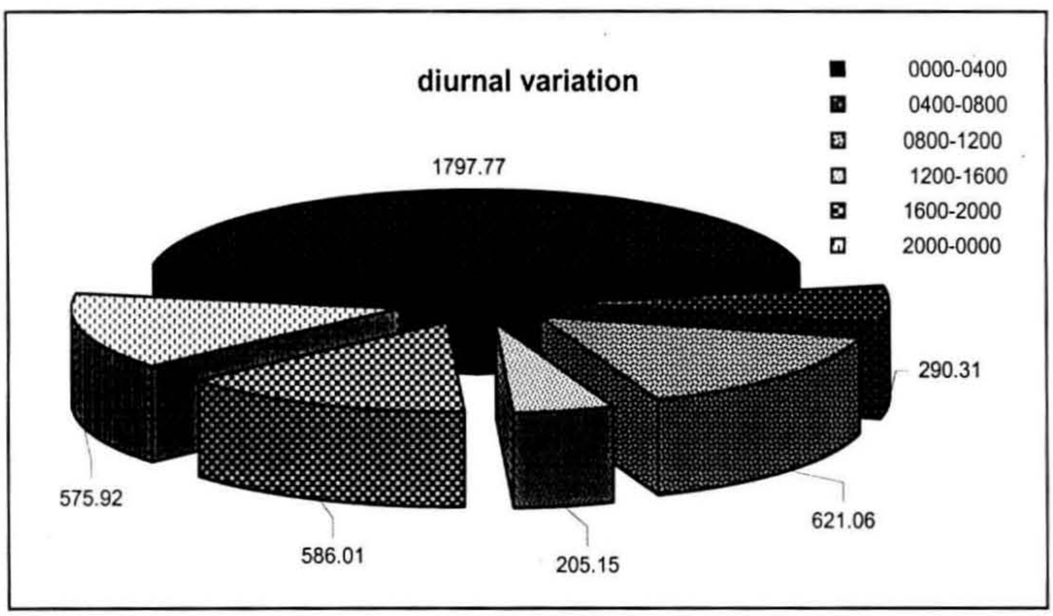


Fig.45. Diurnal variation in the Biomass of Leptocephali

Biomass estimation of major families

The leptocephalid biomass on the south west coast of India was constituted mainly by leptocephali belonging to five families viz. Congridae, Ophichthidae, Muraenidae, Nemichthyidae and Synaphobranchidae (Fig.46). Of the five families leptocephali of Congridae, Ophichthidae and Muraenidae dominated the catch. The representation by the other two families – Nemichthyidae (12 stations) and Synaphobranchidae (11 stations) were very poor in comparison, out of the 84 stations.

Family – Congridae

This was the largest represented family accounting to 30% of the total leptocephalid biomass of the south west coast of India. It had a fairly continuous abundance (in tones) along the south west coast (Fig.47). The abundance was maximum (>1000t) in the 9° latitude, off Cochin.

Geographical abundance

The congrid leptocephali were abundant (in tones) through out the latitudes (6°N – 14°N) with its maximum abundance along the 9° latitude (328.01t), followed by 10° latitude (142.61t) (Fig.48). The abundance along the other latitudes was comparatively less (<100t) with the lowest abundance in the 11° latitude (29.38t).

Day – night variations

a) Latitude wise abundance

Leptocephali of the family Congridae was present through out the latitudes invariably of day and night. In comparison the nighttime biomass (average) was more than day. The highest abundance during night was at the 9° latitude with 789.83t, where as in the other latitudes it was low in comparison (<200t). The daytime high was at 10° latitude (111.95t) (Fig.49)

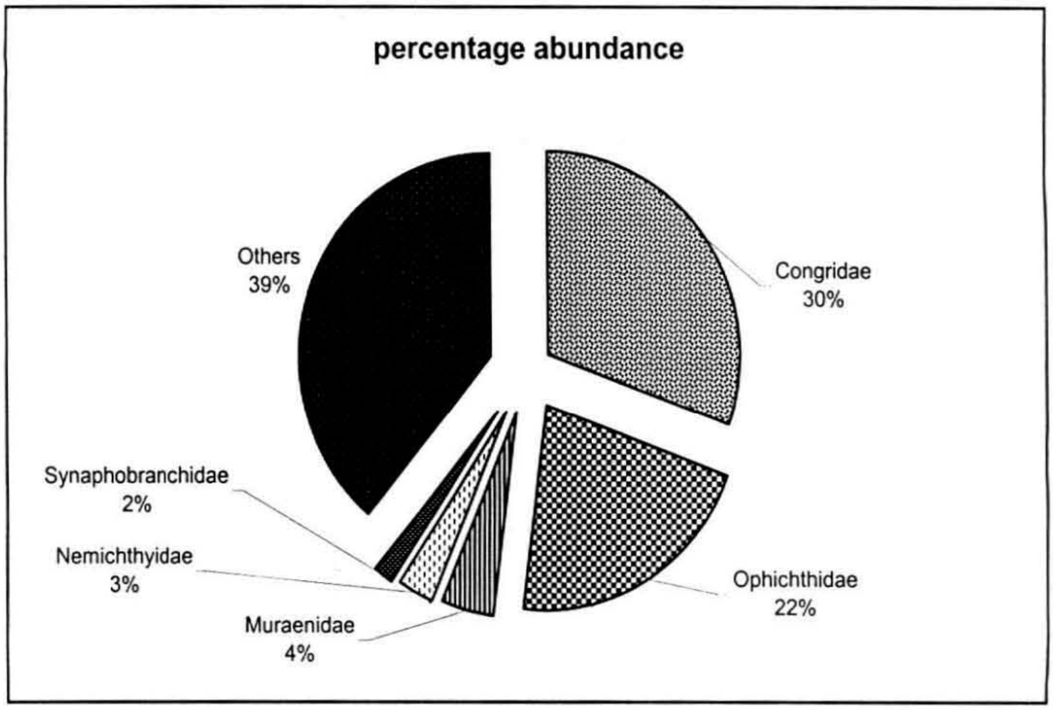


Fig.46. Percentage abundance of major families

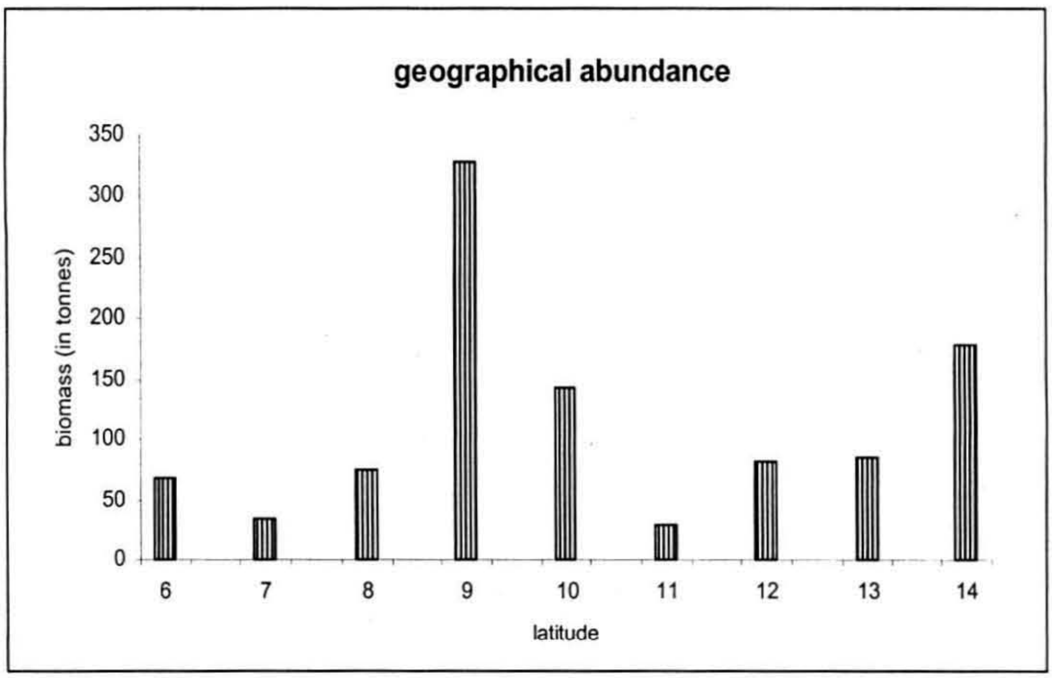


Fig.48. Congridae - Geographical abundance

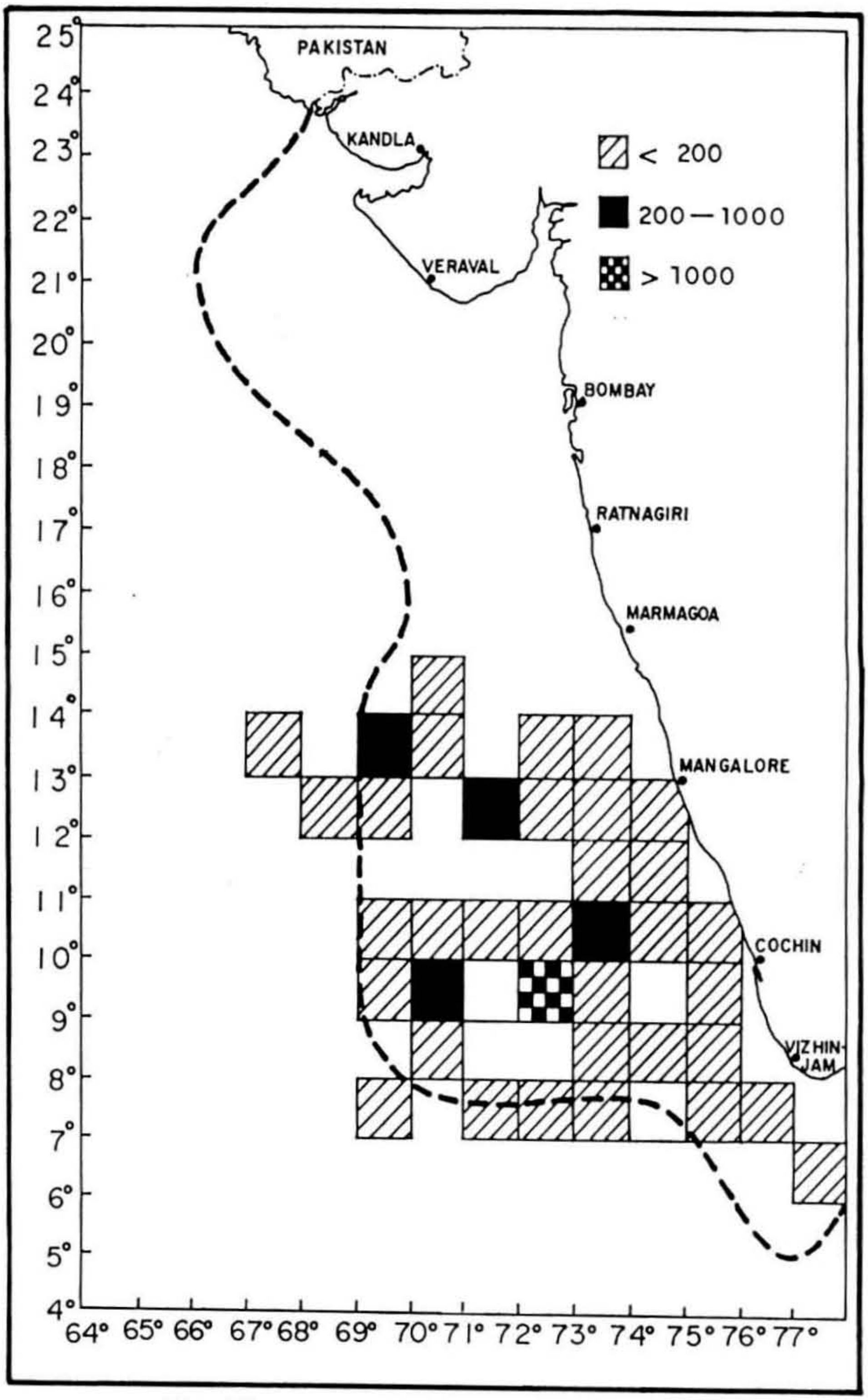


Fig. 47 Congridae – Total Biomass (Tonnes) in the South-West coast of India

b) Monthly variation

The monthly abundance of the congrid leptocephali shows that it was more on the month of September (186.92t) and low on October (7.22t). Diurnal variations were maximum in the month of May with 257.41t (night) and for the day it was the month of September (202.87t). (Fig.50)

c) Vertical abundance

The abundance of the family Congridae was more in the depth range of 0-50m (163.38t). Studies on the diurnal variation shows that the nighttime biomass (average) was more on the surface layers between 0-50m (191.79t), followed by 161.43t in the 50-100m depth range. Daytime biomass (average) was more in the depth range above 300m (Fig.51). In general, the nighttime biomass (average) was high in comparison.

d) Horizontal abundance

Bottom depth wise the congrid leptocephali were abundant more during night with a maximum of 189.73t in the 1000-3000m zone. The day biomass (average) was maximum above 3000m (91.23t). In general, the abundance was more in the 1000-3000m depth zone (266t). It was also noticed that the leptocephali was absent in the shallower region (0-200m). (Fig.52)

e) Temporal variation

The study revealed that the leptocephalid biomass (average) was maximum in the late hours of the day between 20 00-00 00 hours (193.25t), followed by 163.28t in the early hours of the day between 00 00-04 00hours (Fig 53). The least biomass (average) was recorded between 08 00-12 00 hours (32.66t).

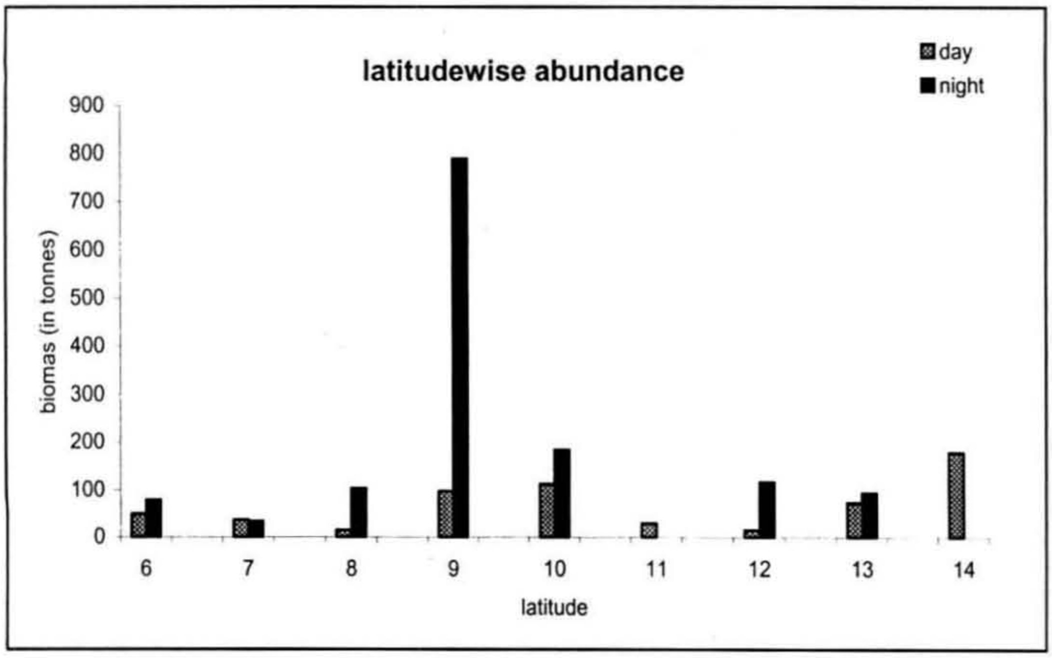


Fig.49. Congridae - Latitude wise abundance (day and night)

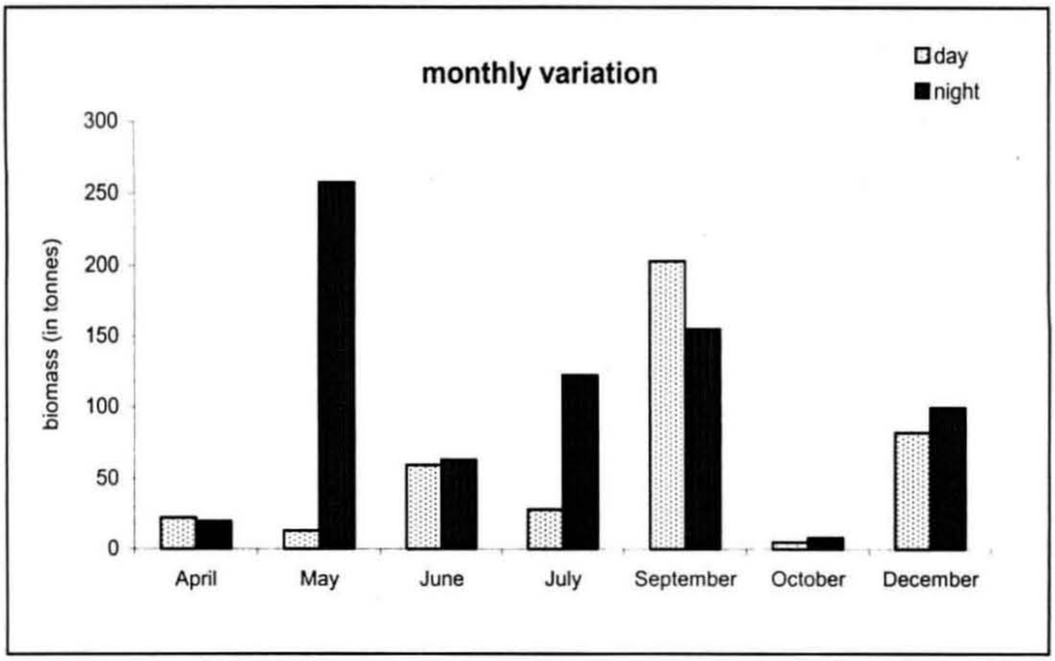


Fig.50. Congridae - Monthly variation (day and night)

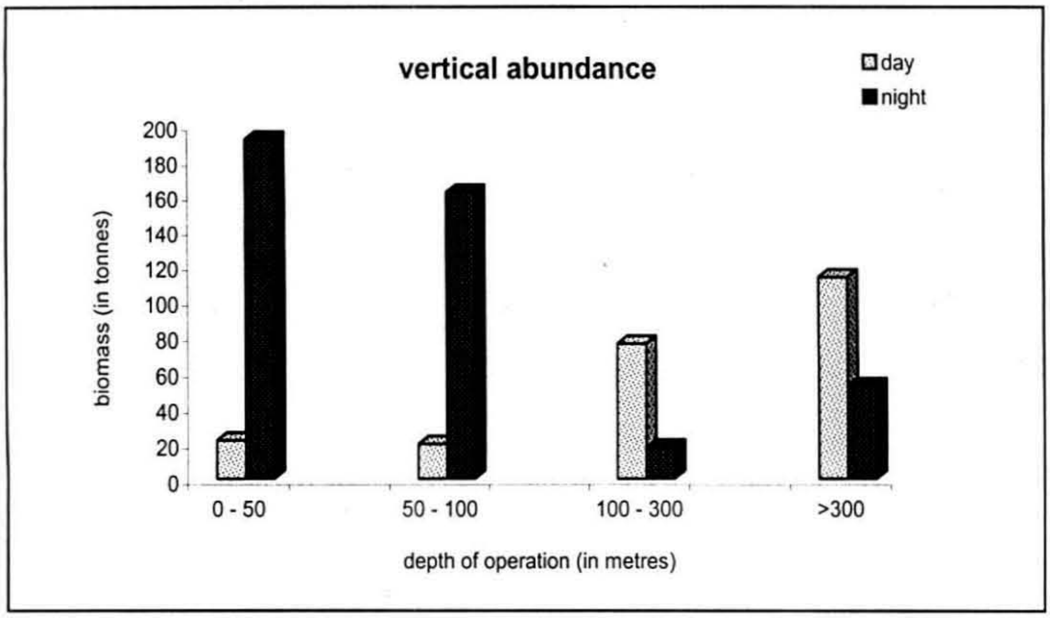


Fig.51. Congridae - Vertical abundance (day and night)

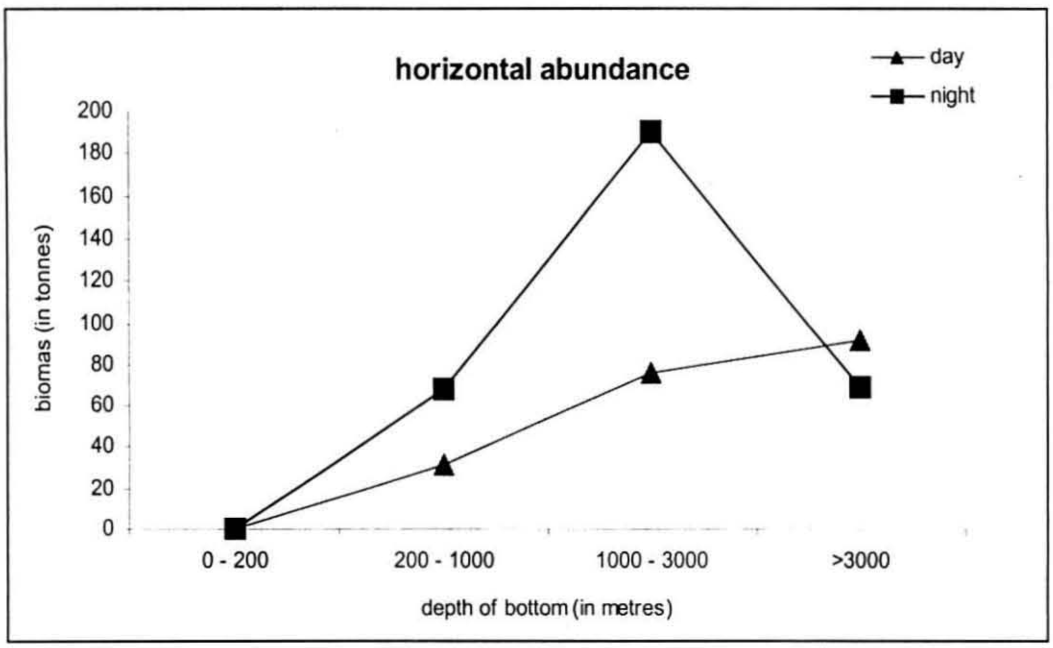


Fig.52. Congridae - Horizontal abundance (day and night)

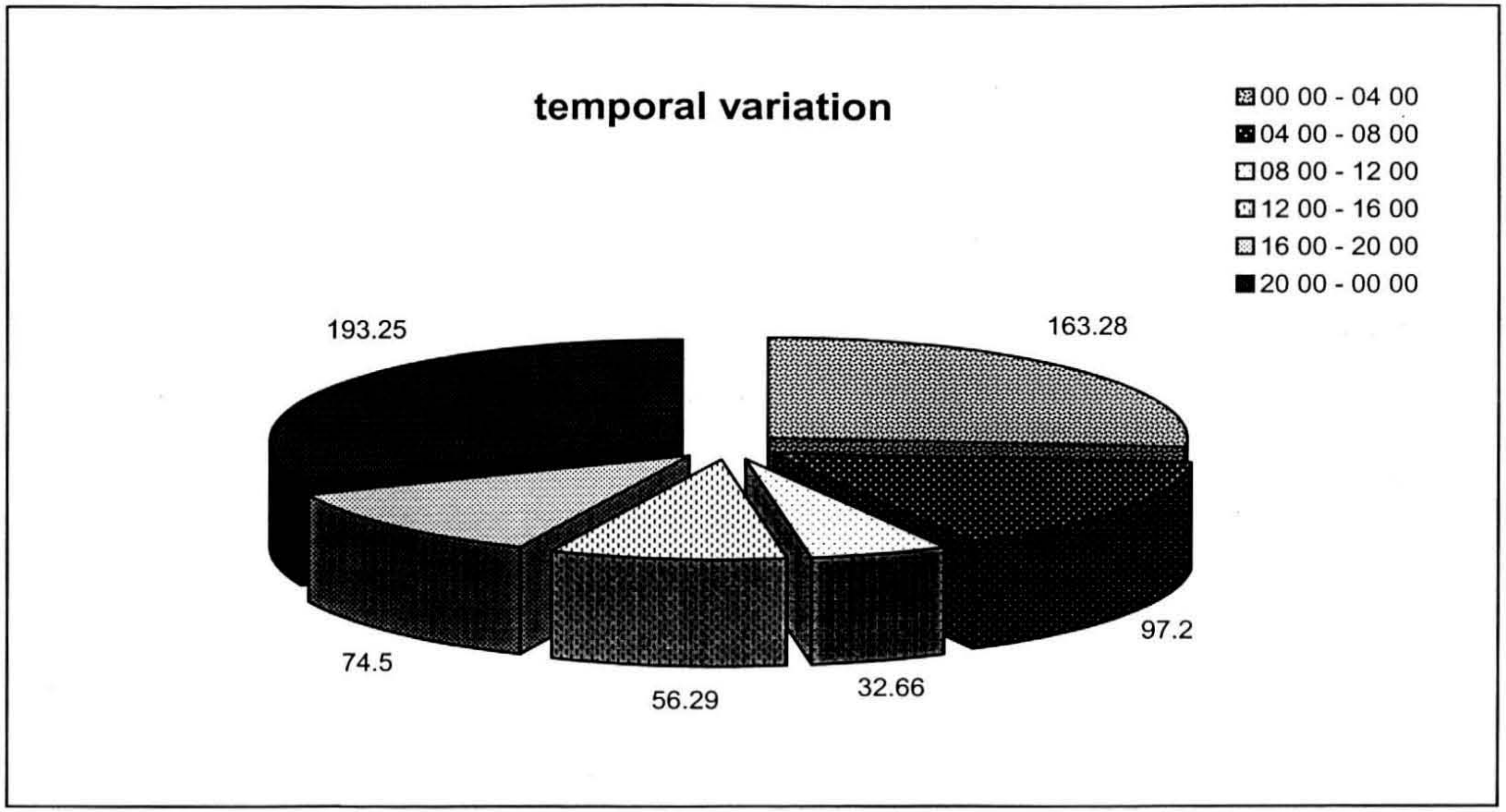


Fig.53. Congridae - Temporal variation (day and night)

Family – Ophichthidae

The second largest abundant family, Ophichthid leptocephali formed 22%of the biomass in the south west coast. Though abundant, the Ophichthid leptocephali do not had a continuous distribution like that of Congridae.

Geographical abundance

Geographical abundance (in tones) shows that the ophichthid leptocephali were denser in the area off Mangalore (12° latitude) with a single high density area (>1000t). Towards the south abundance was less (<200t) in comparison but more or less evenly distributed. (Fig.54)

Day- night abundance

a) Latitudinal variation

Latitude wise the leptocephalid biomass (average) of the family Ophichthidae was high in 12° latitude (338.94t). Day night variations show that the night biomass (average) was more in the 12° latitude (440.37t) and 38.97t in the 9° latitude during day. (Fig.55)

b) Monthly variation

Studies revealed that the monthly abundance was maximum in the month of July with 688.6t and a lowest of 9.9t in June. Day-night variations in biomass (average) were maximum in the month of July (1013.11t) during night and October (336.46t) for day. (Fig.56)

c) Vertical abundance

Diurnal variations in the vertical abundance (depth of operation) of ophichthid leptocephali were maximum in the 50-100m range for night (261.68t) and 80.82t for day in the depth range above 300m. In general, the biomass (average) was maximum in the 50-100m depth range (285.18t). (Fig.57)

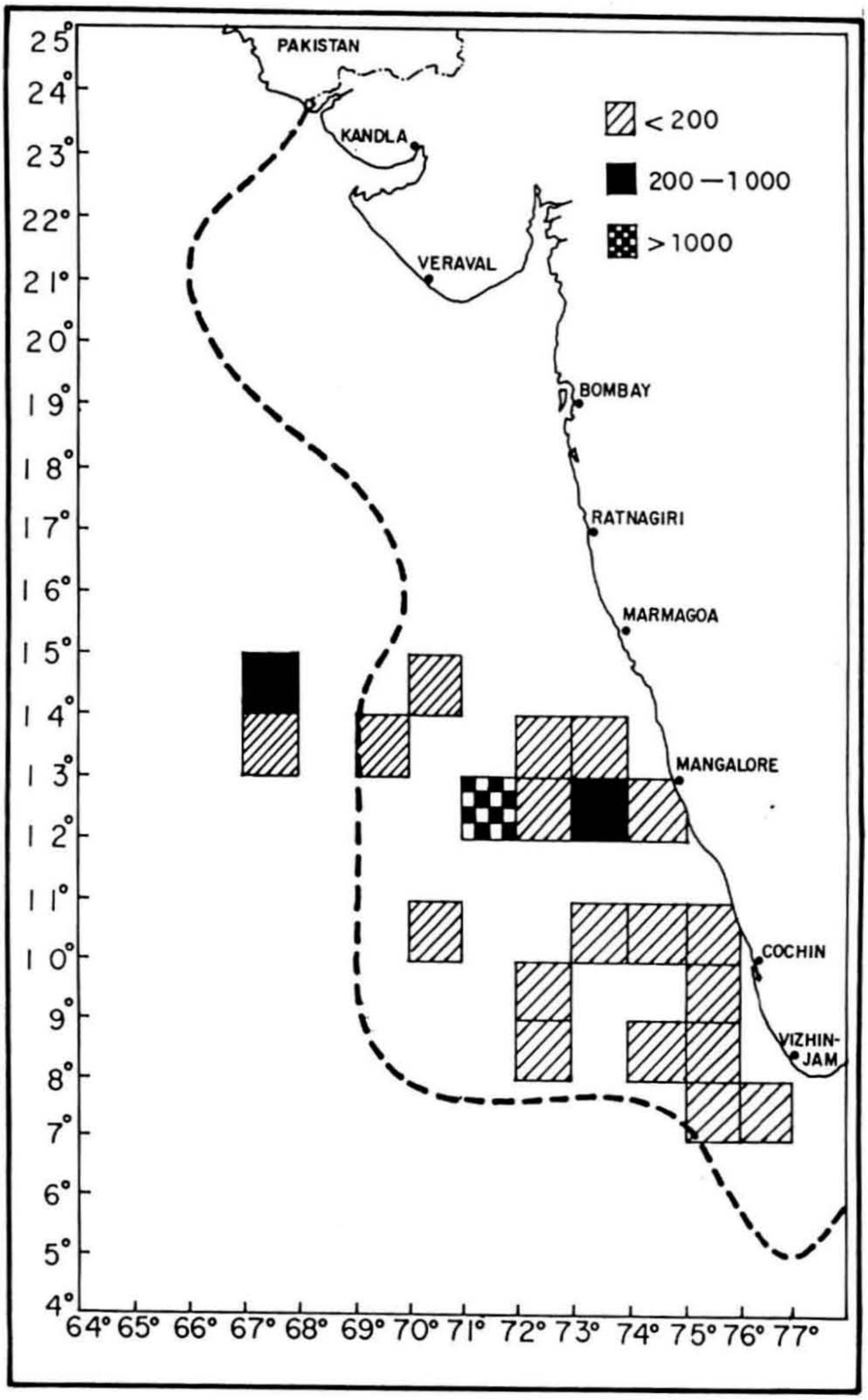


Fig. 54 Ophichthidae – Total Biomass (Tonnes) in the South-West coast of India

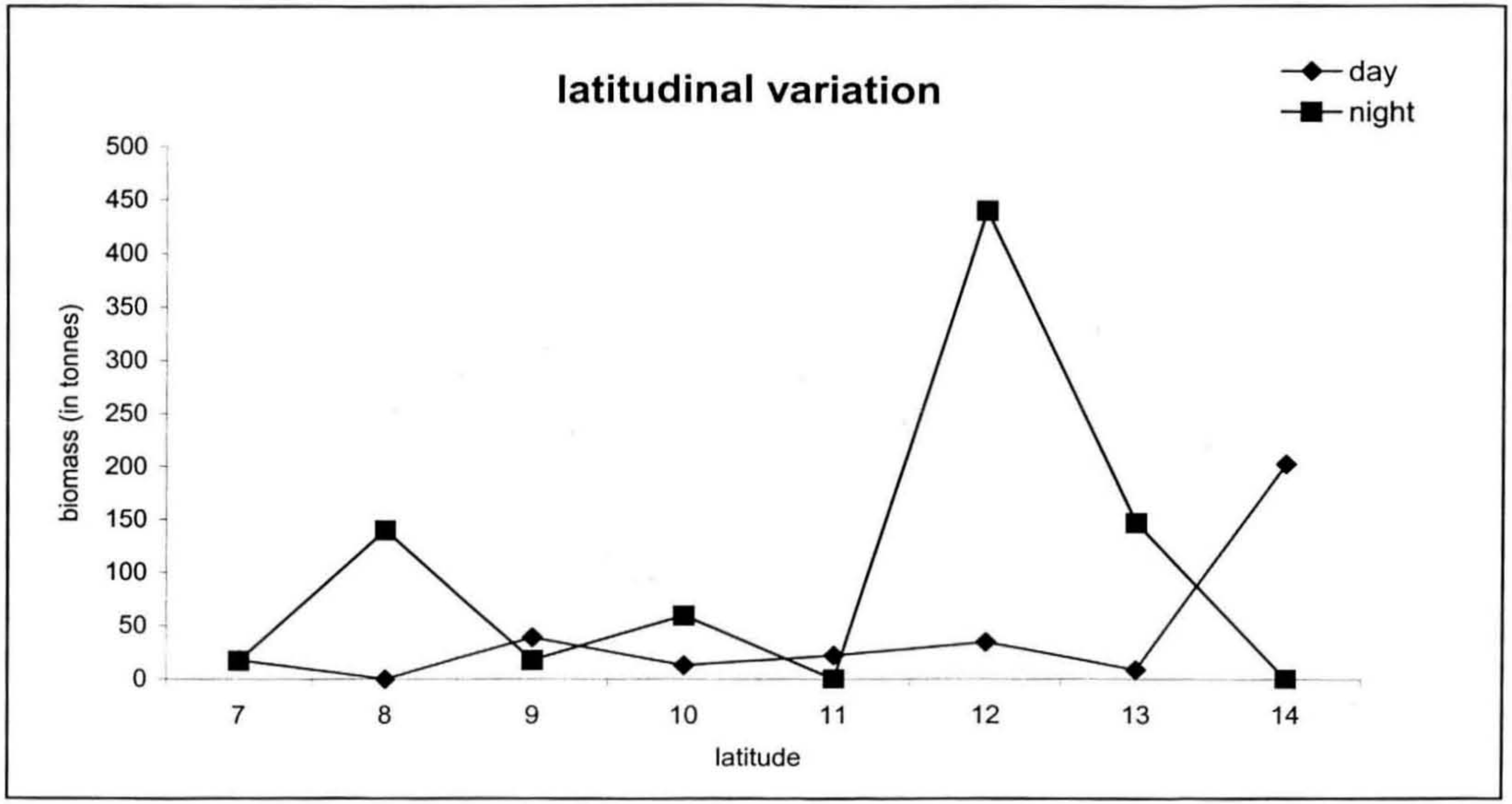


Fig.55.Ophichthidae - Latitudinal variation (day and night)

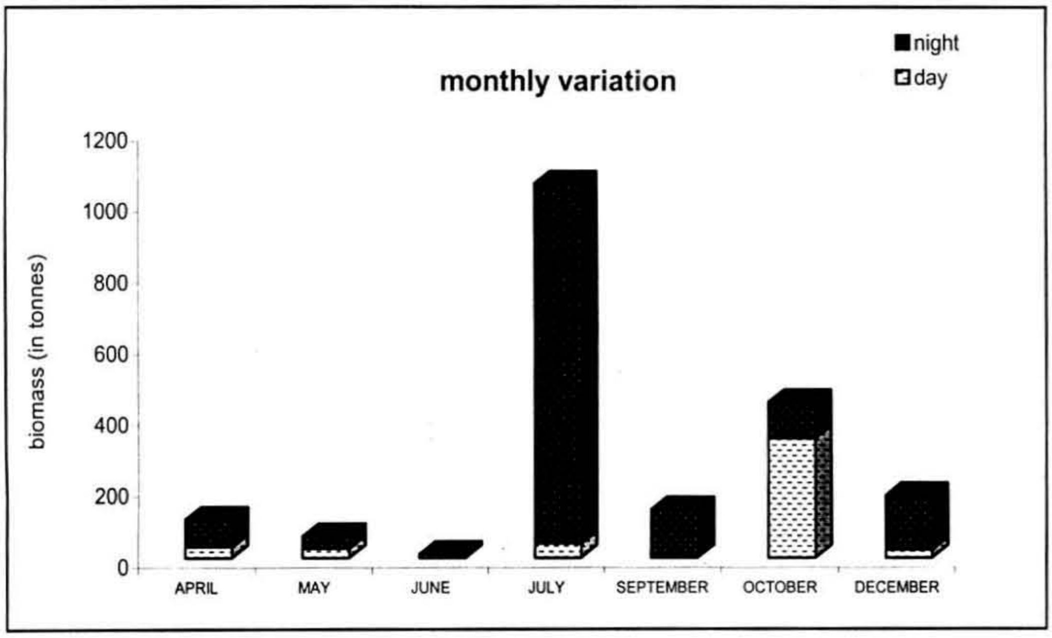


Fig.56. Ophichthidae - Monthly variation (day and night)

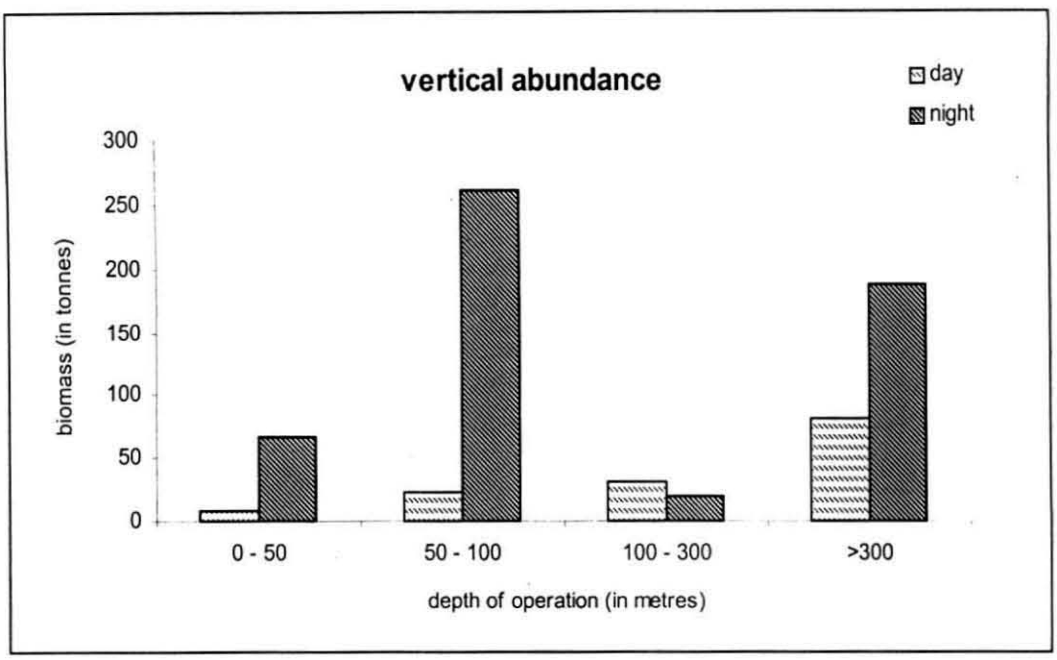


Fig.57 Ophichthidae - Vertical abundance (day and night)

d) Horizontal abundance

Analyses revealed that there is a gradual increase in the total biomass (average) with the increase in bottom depth up to the 1000-3000m mark (141.95t) after which it decreases (Fig.58). Diurnal variations show that the nighttime biomass (average) was more in the 1000-3000m depth zone (191.31t). The daytime average biomass was more in the zone above 3000m (202.87t) where as in the other depth zones it was comparatively very less (<30t) (Fig.59).

e) Diurnal variation

Diurnal abundance was more during the early hours of the day between 00 00-04 00 hours (534.38t), followed by 390.07t between 04 00-08 00 hours. Rest of the day the average biomass was well below 100t, with the lowest of 12.99t between 08 00-12 00 hours. (Fig.60)

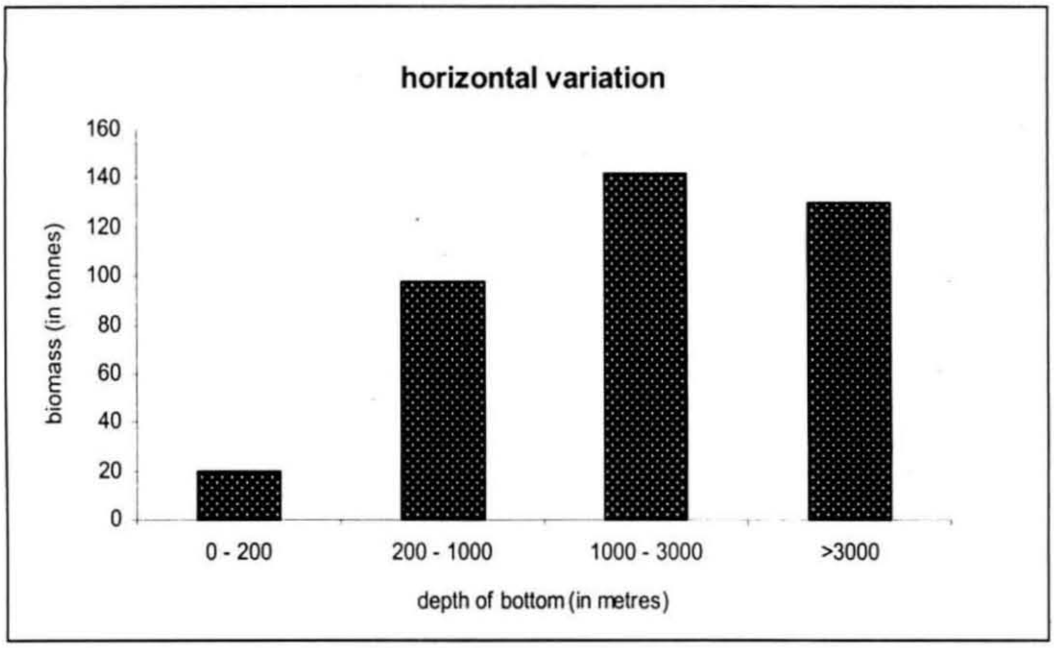


Fig.58. Ophichthidae - Horizontal variation

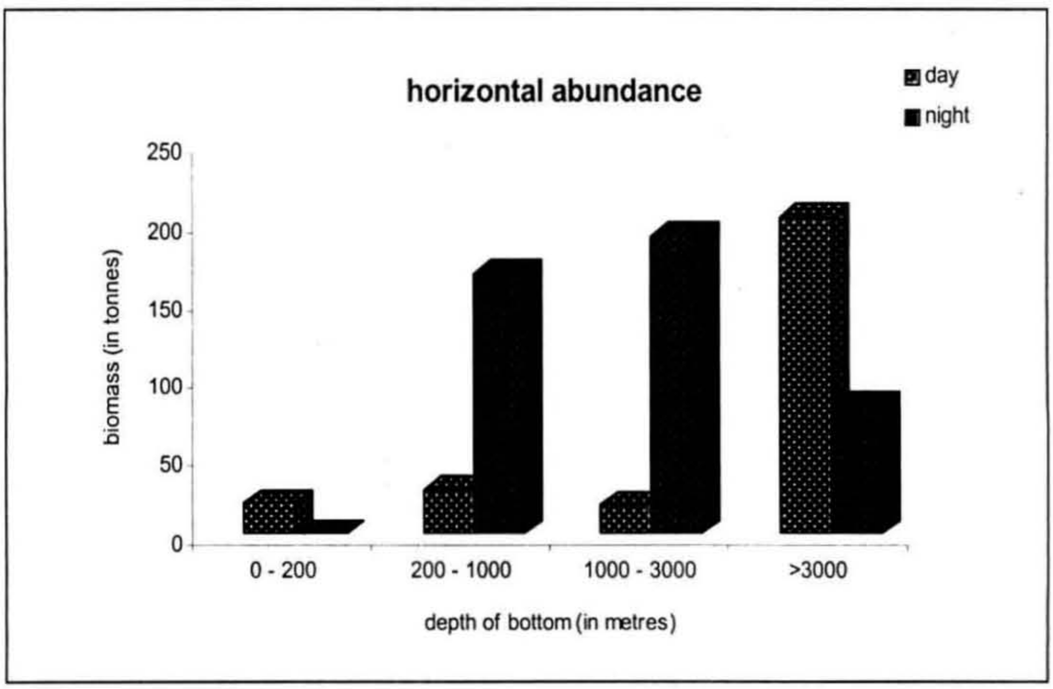


Fig.59. Ophichthidae - Horizontal abundance (day and night)

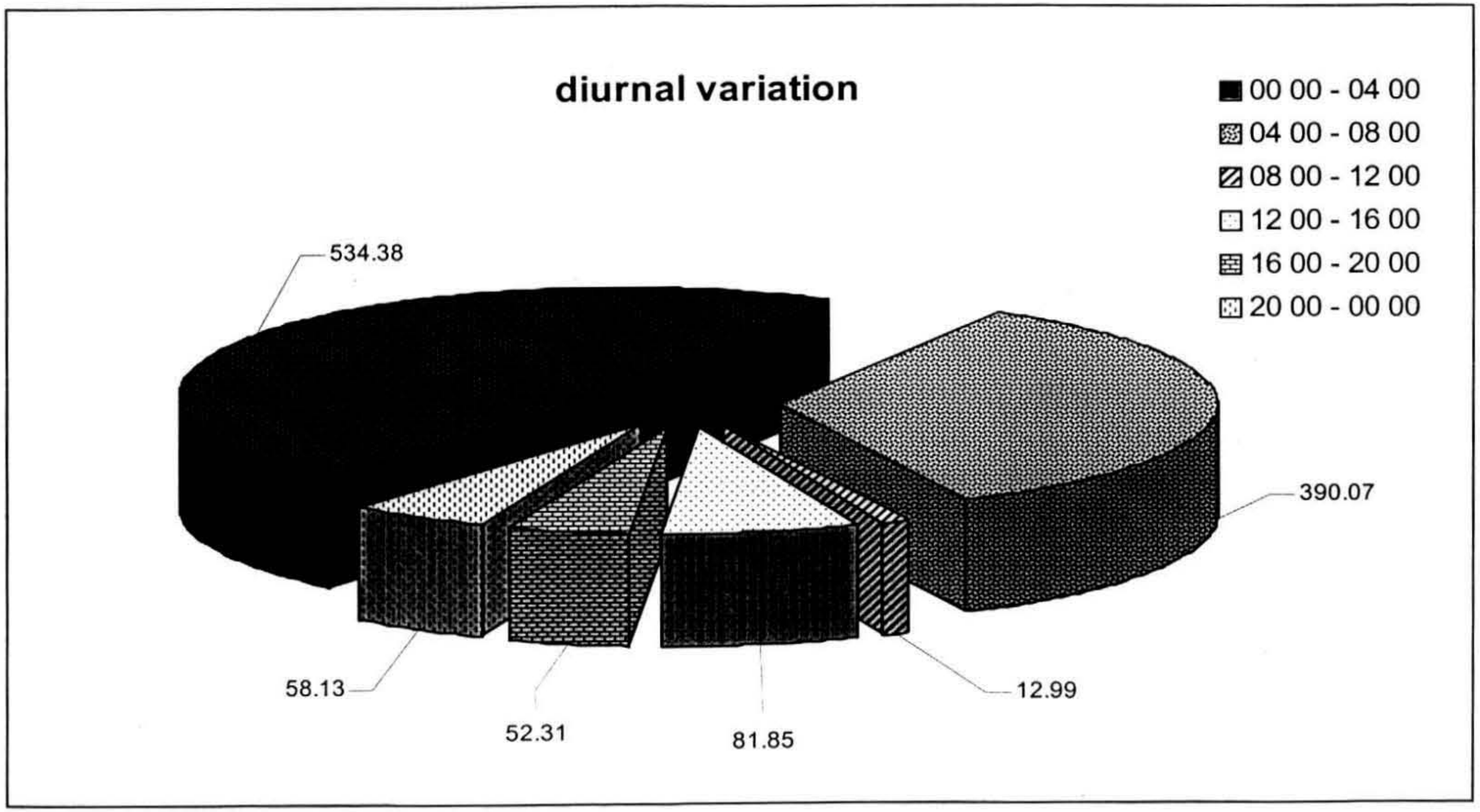


Fig.60. Ophichthidae - Diurnal variation

Family - Muraenidae

Though the third largest family in the leptocephali collection of the south west coast of India, the percentage concentration of the family Muraenidae was very less in comparison with the other two families viz. Congridae and Ophichthidae, forming only 4% of the total biomass. It was present on 27 stations out of the 84 stations sampled.

Geographical variations

The abundance (in tones) of muraenid leptocephali was more or less even towards the south with two high density areas- one on 9° latitude, off Cochin and the other off Mangalore on 12° latitude. (Fig.61)

Day-night variations

a) Latitudinal variation

The studies revealed that the nighttime average biomass (in tones) was high in 13° latitude (108.86t) where as the day in 9° latitude (46.39t) (Fig.62). In general, the average biomass was maximum in the 13° latitude (64.63t).

b) Vertical and horizontal variations

Analyses revealed that vertically (depth of operation) the muraenid average biomass (in tones) was more in the 50-100m depth range (41.39t) during night and in the 100-300m depth range during day (43.54t) (Fig.63). Horizontally (depth of bottom) the nighttime biomass (average) was high in the 200-1000m depth zone, where as that of day in the depth above 3000m (52.78t). The muraenid leptocephali were totally absent in the 0-200m depth zone (Fig.64).

c) Monthly abundance

The monthly variations in average biomass plotted almost similar higher values in two months- September (60.62t) and December (60.38t). Day-night variations in average biomass shows that the nighttime biomass was high in the month of December (80.16t) and that of day in September (66.80t). (Fig.65)

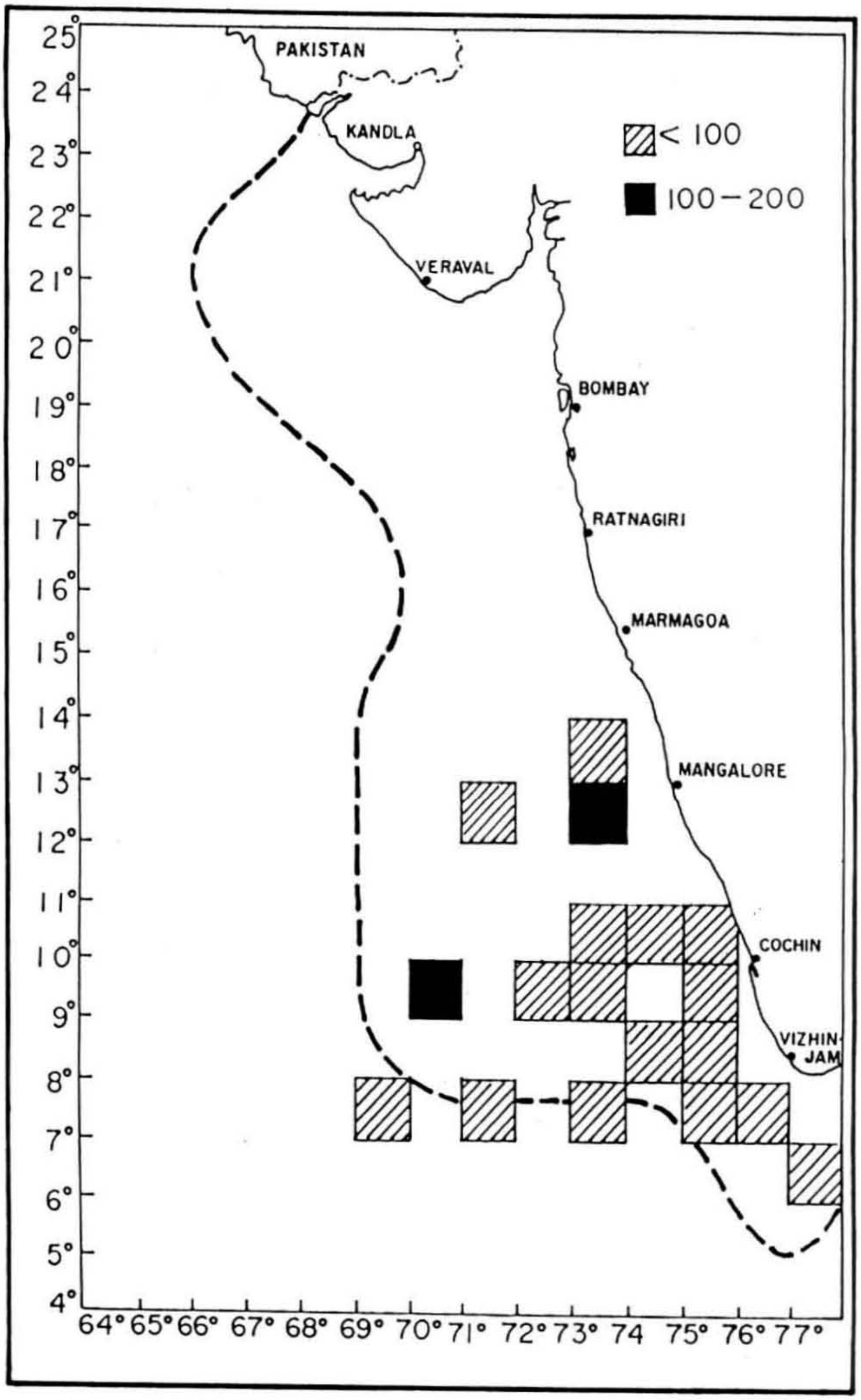


Fig : 61 Muraenidae Total Biomass (Tonnes)
in the South West Coast of India

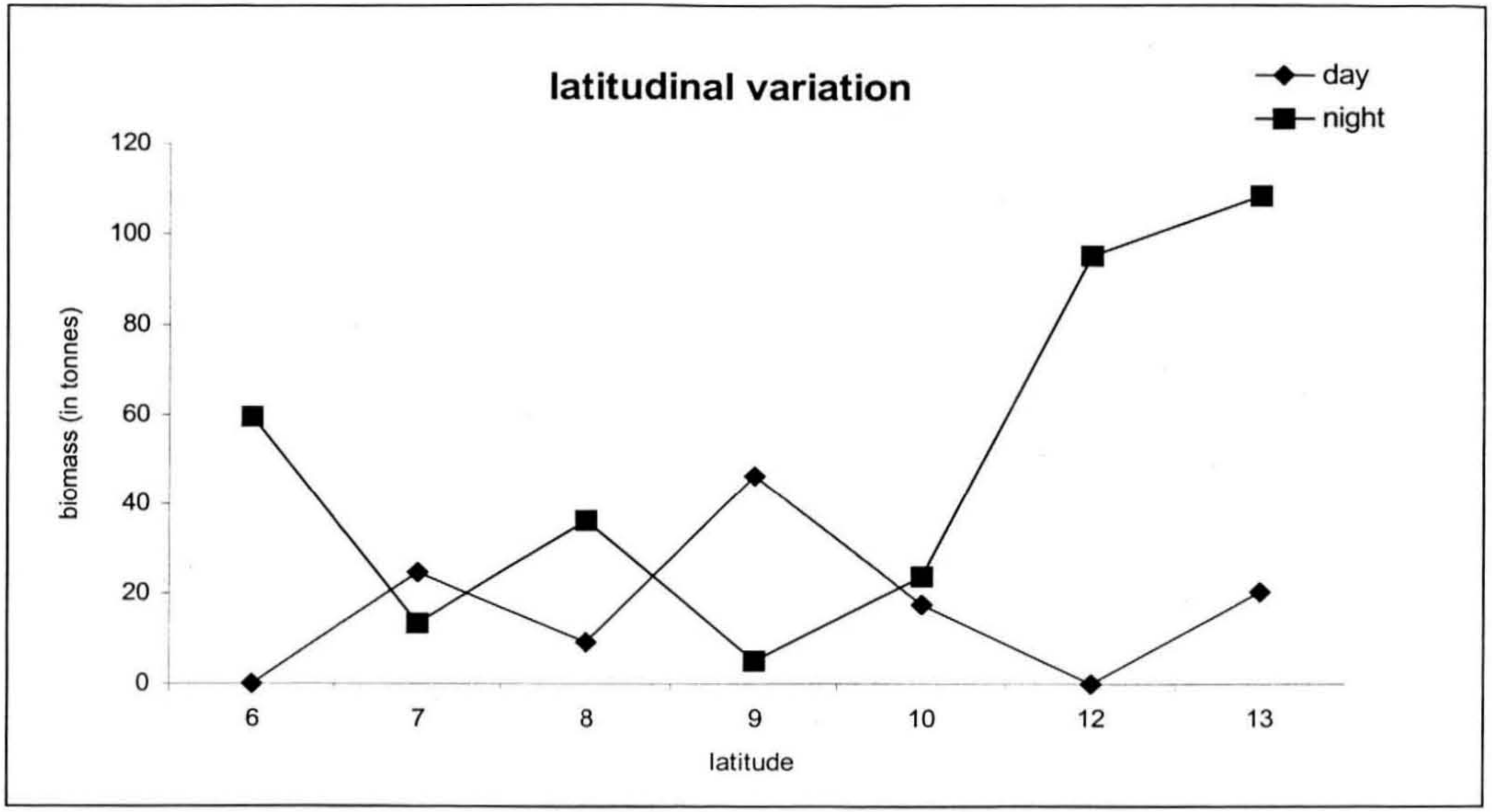


Fig.62. Muraenidae - Latitudinal variation (day and night)

d) Diurnal variation

The estimated average biomass plotted a higher value of 185.55t between 00 00-04 00 hours of the day. The biomass recorded a low value between 08 00-12 00 hours (18.56t). (Fig.66)

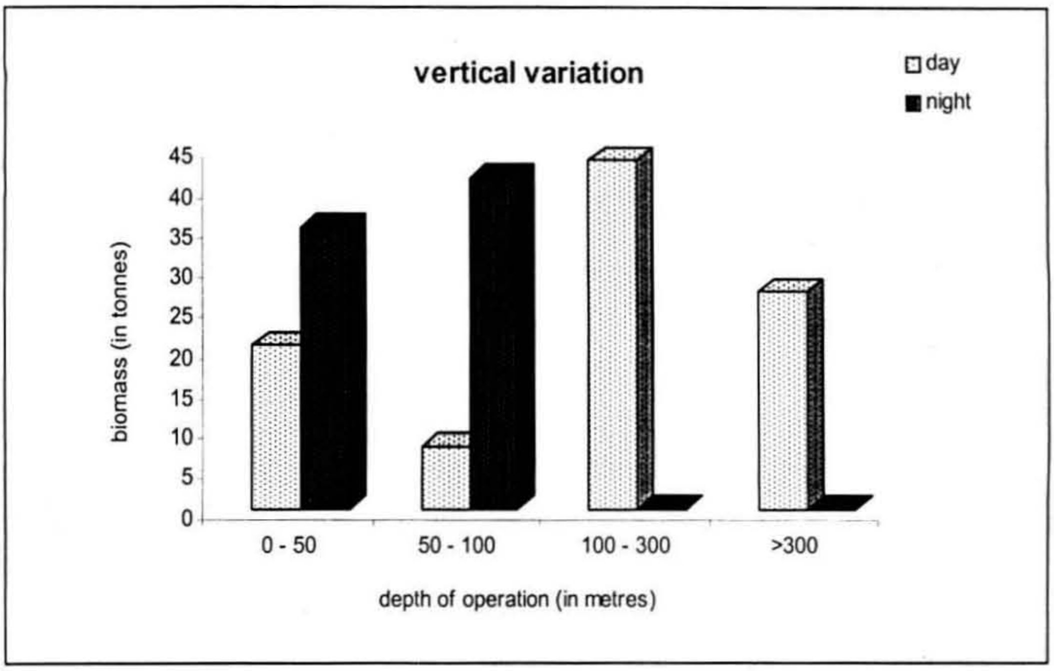


Fig.63. Muraenidae - Vertical variation (day and night)

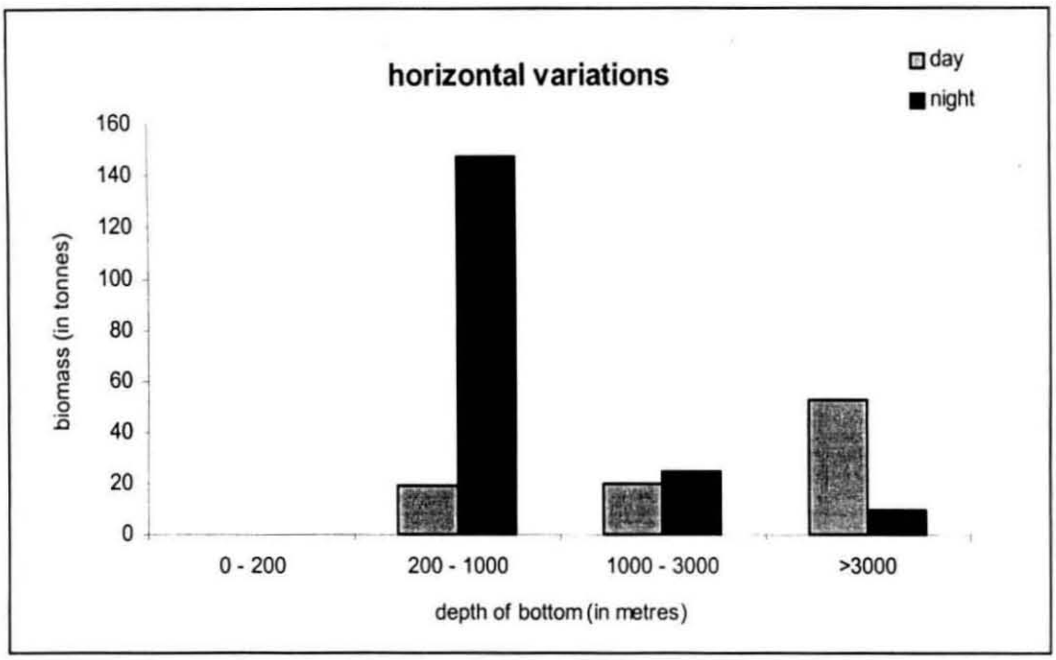


Fig.64. Muraenidae - Horizontal variation (day and night)

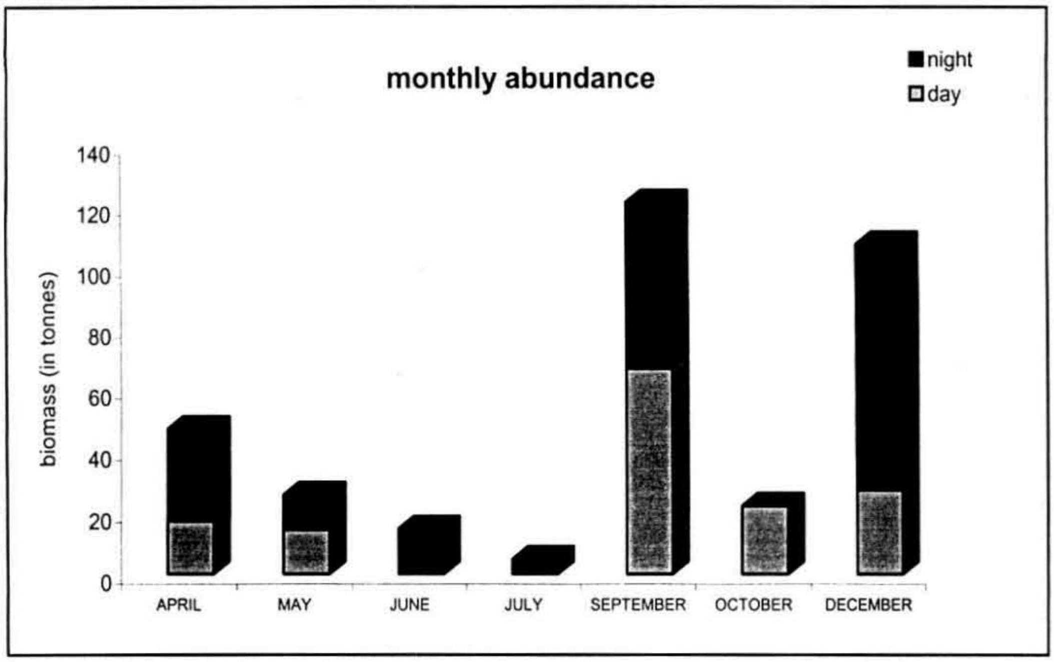


Fig.65. Muraenidae - Monthly abundance (day and night)

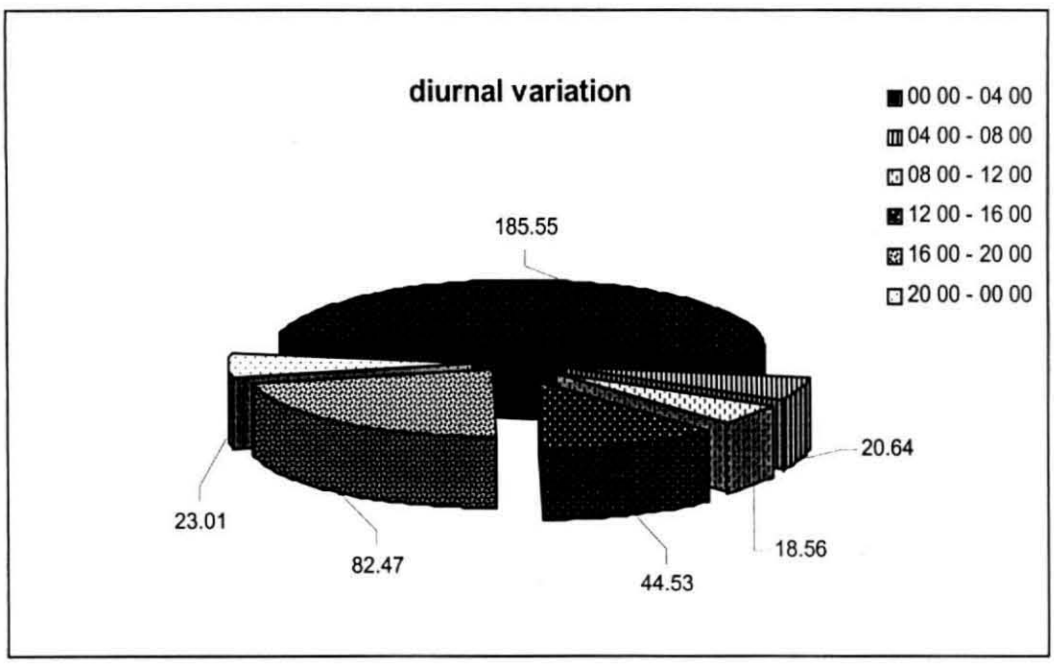


Fig.66. Muraenidae - Diurnal variation (day and night)

Discussion

Discussion

The Deep Scattering Layer (DSL) is very rich in the quantitative abundance of micro and macro nekton. Leptocephali formed one of the major groups in the total nektonic biomass of the samples collected from the Arabian Sea. It constituted to about 7.5% of the total fish biomass in the DSL of the EEZ of India (Menon, 1990). The leptocephali were represented mainly by 8 genera viz. *Uroconger, Ariosoma, Ophisurus, Ophichthus, Phaenomonas, Gymnothorax, Uropterygius, Anarchias*, 2 species (*Uroconger lepturus* and *Congrellus anago*) and some unidentified types belonging to five families viz. Congridae, Ophichthidae, Muraenidae, Nemichthyidae, and Synaphobranchidae.

The historic studies made by Johannes Schmidt (1922a) on larvae of the North Atlantic species of *Anguilla* and later by Jespersen (1942) on Indo-Pacific Anguilla larvae are the most informative works available on the early life histories of eels.Very few works have been carried out on leptocephali in general, especially on systematics of leptocephali from the Indian Seas. Some of the earlier workers who described the leptocephali include Risso (1810), Cocco (1829), Lesson (1830), Costa (1844, 1856), Kolliker (1853), Kaup (1856 b), Peters (1859, 1864), Day (1865a,) Southwell and Prashad (1919), Delsman (1933), Deraniyagala (1934), Bertin (1935a), Beebe (1935b), Beebe and Crane (1936, 1937 a,b), Ege (1939), Jesperson (1942), Aiyar *et al.* (1944), Gopinath (1946, 1950), Nair (1946,1948), Nair and Bhimachar (1950), Bapat (1955), Jones and Pantulu (1955)etc. In the 1960's the tempo of work on the leptocephali began to accelerate, corresponding to an increased attention to the systematic relationship of eels with many workers like Nair and Bhimachar (1960), Nair and Dharmamba (1960), Nair and Mohamed (1960 a,b,c,d,e), Ganapati and Raju (1960, 1963), Orton (1963, 1964a,b), Castle (1964a, 1965a,b,c,d, 1969c) etc. contributing to it. A preliminary systematics of leptocephali from the Indian waters was done by Gopinath (1946,1950) from the Trivandrum coast. He described the leptocephali of *Muraenesox cinereus*, *Congrellus anago* and a few unidentified leptocephali. Larvae of *Congrellus anago* (Congridae) were present in considerable numbers in the present collection. The characteristic feature of this larva appears to be the presence of stellate chromatophores on the base of anal and caudal fin rays as described by Nair (1948). The later authors (Castle 1964a, Mochioka *et al.*, 1991) described the same as *Ariosoma scheelei* considering it as a synonym of *C. anago*. The study specimen also coincides well with the characters described by the above authors. In spite of these some other workers also described a few leptocephali like *Leptocephalus milnei* (Southwell and Prshad, 1919), Larva I of Deraniyagala (1934) etc., which a resemblance with *C. anago* but their identity cannot be determined as they were poorly described. The myomere numbers in the above specimens varied between 108-120, where as in the study specimen it was 118.

Another dominant leptocephali in the sample analysed was of *Uroconger lepturus* (Congridae). The distinguishing character of this larva is the presence of group of black, branched chromatophores below the eye. Other characters include the presence of a single series of midlateral melanophores and ventral pigment extending the length of the body. This larva was earlier described by Nair (1946,1948), Nair and Mohamed (1960c) and Socolovski (1975). Smith (1979) described the above larval characters as common to three genera of Congridae viz. *Uroconger*, *Rhechias* and *Pseudoxenomystax*. Among this the genus Uroconger can be distinguished by their high myomere count (more than 200). The study specimen very well confirms with the distinguishing characters described above and also has more than 200 myomeres.

Ariosoma type – Exterillium larvae with an outer intestine was earlier described by Mochioka *et al.*(1982) and James and Prabhadevi (1990). There are a few unidentified leptocephali whose identity cannot be ascertained with certainty.

The leptocephali of the family Ophichthidae can be identified by the thickenings or humps or loops (three or more) on the intestine, which is a characteristic feature. In the present study it was identified to the genus level viz. *Ophicthus*, *Ophisurus* and *Phaenomonas*. The eggs and larvae of the family Ophichthidae was described by authors like Delsman (1933), Jones and Pantulu (1955), Ganapati and Raju (1960), Nair and Dharmamba (1960), Nair and Mohamed

(1960d), Castle (1965c), Fahay and Obenchain (1978), Smith (1979), Rani Mary George (1987) and others. Few unidentified leptocephali were also present in the collection.

The muraenid leptocephali have been described by many authors like Nair (1947, 1948), Pantulu and Jones (1954), Castle (1965b), Bensam (1966), Smith (1979, 1989h) etc. The larva can be identified by the presence of a greatly reduced pectoral fin, a moderate to deep body and with a characteristic round caudal fin with the dorsal and anal fin restricted to it. Three genera of muraenid larvae have been identified in the present study viz. *Gymnothorax*, *Uropterygius*, and *Anarchias*. The systematics of the leptocephali of the two families viz. Nemichthyidae and Synaphobranchidae have so far not been carried out from Indian waters except for some studies by Castle (1965 a), Smith (1979) etc. A few unidentified leptocephali constituted the two families in the present study. Considerable advances are possible in the systematics and general biology of eels once their larvae have been identified.

In the present work an attempt is made to study the metamorphosing stages of *Congrellus anago* from the Indian waters. Metamorphosing stages of the leptocephali was described by various authors. Some of the earlier workers include Delage (1886), who confirmed Gill's (1864) hypothesis by raising a specimen in an aquarium where as the first account of eel eggs was given by Raffaele (1888) who studied the early development of five types of unidentified eggs from the Bay of Naples. In India, the earlier studies on the different stages of metamorphosis of eel larvae were carried out by Nair (1947) on the leptocephali of *Muraenesox cinereus* and *Muraena macrura* and later on by Jones and Pantulu (1952), Pantutlu and Jones (1954), Nair and Dharmamba (1960), Nair and Mohamed (1960 a,b,c) and Ganapati and Raju (1960).Castle (1970b) studied the metamorphosis of the eel *Derichthys serpentines* (Derichthyidae) from the South Atlantic.

The leptocephali were found to have a wide distribution along the west coast of India from the coastal waters to the deep sea. The study revealed that the occurrence of leptocephali was maximum during monsoon period. The highest abundance of 18.32 no/1000m^3/haul was recorded at the 12°30 latitude and 71° 29 longitude. Comparatively the night abundance was high (154.95 no/1000m^3) than the day (57.32 no/1000m^3). Miller *et al.* (2002) in their study on the leptocephali of Kuroshio Current region and east China Sea found that there is no significant difference between oblique or step tows or tows made during day time, at night, around sun set, or around sunrise. This is in contrast to collections with an IKMT in the clear, lower productivity water of the open ocean, where catches of leptocephali during the day have been found to be significantly lower than those at night (Miller and Mc Cleave, 1994).

Earlier studies on the distribution of anguillid leptocephali (Kleckner and Mc Cleave, 1985) have revealed that the high concentration follows the areas of upwelling and circulatory currents in the Ocean. Nair (1947) stated that there is no seasonality in the occurrence of leptocephali and the eels in the tropics breed through out the year. Seasonal variation in the abundance of ichthyoplankton in the Arabian Sea (Peter, 1973) was observed maximum during southwest monsoon in areas of upwelling and places under the influence of divergence. Miller *et al.* (2002) studied the distribution of leptocephali in the Kuroshio Current and East China Sea and stated that the most abundant leptocephali in the region were of the eel families Congridae, Synaphobranchidae, Ophichthidae, Muraenidae and Nettastomatidae. Distribution of leptocephali from the Indian seas were carried out by James and Prabhadevi (1990), where they studied the distribution in the Deep Scattering Layer of the Indian EEZ and observed that the occurrence and distribution of leptocephali indicated that maximum number of larvae and positive stations were located in the Arabian Sea where high salinity water mass (Sen Gupta *et al.*, 1976) existed. They concluded that the distribution of leptocephali in Bay of Bengal and the equatorial water were less when compared to Arabian Sea and also stated that the occurrence of leptocephali showed maximum during post monsoon and pre monsoon periods even though regular seasonality was not observed in seas around India.

Physical and behavioural controls on the oceanic distribution and migration of leptocephali in the Subtropical Convergence Zone within the Sargasso Sea

(Mc Cleave, 1993) where the spawning and distribution of leptocephali of five families of eels were studied. He concluded that the distribution across fronts of leptocephali of the catadromous species of *Anguilla*, shelf dwelling species and oceanic species are different in winter. Wippelhauser *et al.* (1996) studying the spawning and larval distribution of Snipe eels (Family Nemichthyidae) in the Sargasso Sea stated that small *Nemichthys scolopaceus* leptocephali (6-15mm) were abundant in February-April and smaller leptocephali were consistently more abundant, but larger leptocephali were more widely distributed. The study by Castonguay and Mc Cleave (1987) determined the distributions and abundances of two of the most abundant leptocephali, *Derichthys serpentines* and *Nessorhamphus ingolfianus* (Derichthyidae) in the western Sargasso Sea in summer and fall, related the distributions to oceanic features and contrasted the distributions with those of *Anguilla rostrata* and *A. anguilla* (Angullidae) with respect to retention in the oceanic realm. Castle (1970b) stated the distribution of *Derichthys serpentinus* (Derichthyidae) in the Indo-West Pacific also, as well as in the Atlantic and east Pacific.

The dynamic circulation around the Bahama Banks, when and where shelf eels spawn in relation to these banks may have a significant effect on how their leptocephali are distributed in the Sargasso Sea and Florida Current region (Miller, 1995). The spawning locations in the Sargasso Sea and the general distribution of the leptocephali of the American and European eels (Schmidt, 1922a; Schoth and Tesch, 1982; Kleckner *et al.*, 1983; Boetius and Harding, 1985; Kleckner and Mc Cleave, 1985,1988; Wippelhauser *et al.*, 1985; Castonguay and Mc Cleave, 1987; Mc Cleave and Kleckner, 1987; Tesch and Wegner, 1990) are relatively well known.

The family Congridae constituted as the most abundant family with a percentage abundance of 44% of the total in the south west coast of India. Maximum concentration was found in the 10° and 9° latitude, together accounting to about 79.18% in the south west coast. Month of May recorded the highest percentage abundance of 80.04. Night catch was high with an average of 1.03 no/1000m^3. General catch trend also shows that nighttime represented maximum share (82.19%).

Ophichthidae formed as the second largest (30%) family in the collection. It shows a maximum aggregation (78.08%) in the 12° latitude (off Mangalore). Monthly abundance was maximum during the month of July (73.66%). Night catch constituted high with a total of 21.21 no/1000m^3 and day a low of 1.63 no/1000m^3. The concentration was high in the depth of 50-100m (depth of operation) with a percentage abundance of 86.59. There was an increase in the percentage abundance of leptocephali in relation to the increase in the depth of bottom, with a maximum recorded at the 1000-3000m depth zone (85.49%) after which it decreases.

Another dominant family though in less number was Muraenidae with a presence of only 2.65% of the total. The leptocephali had an evenly distribution with no dense pocket of abundance. The percentage abundance was maximum (61.11) in the depth of 50-100m (depth of operation). There was a total absence of muraenid leptocephali in the 0-200m (depth of bottom) depth zone with a maximum in the 1000-3000m (50%).

Family wise distribution of leptocephali has so far not been reported from Indian Seas. Some studies have been reported from the world Oceans (Castle, 1969b; Wippelhauser *et al.*, 1985,1996; Castonguay and Mc Cleave, 1987; Kleckner and Mc Cleave, 1985, 1988; Mc Cleave, 1993; Mc Cleave and Miller, 1994; Miller and Mc Cleave, 1994; Miller, 1995; Miller *et al.*, 2002;). Without having adequate data of the pelagic trawl catch and relating it to the major oceanographic parameters, it is impossible to locate the breeding grounds of eels in the Indian Seas.

Biomass of leptocephali has not been worked out except for a few scattered works. Castle (1969) working on the samples from the eastern Indian Ocean (110°E) stated that the biomass was greatest during early winter at 26°S, but other maxima occur in early winter from 9°S to 17°S and at 23°S during mid summer. In India, no such studies have been carried out so far and the present one being the first study in these lines. In the present study the biomass of Congridae, Ophichthidae, and Muraenidae were estimated. The family Congridae accounting 30% of the total leptocephalid biomass followed by Ophichthidae (22%) and Muraenidae (4%). Nemichthyidae and Synaphobranchidae formed only a negligible percent of the total biomass. The spatial and temporal variation of the biomass of the leptocephali was estimated in the present study for the first time along the south west coast of India. The present study revealed that the biomass of leptocephali was maximum in the north west coast with maximum of 6481.88t in the area 19° N-68 E°. Overall the night biomass was maximum with an average of 1797.77t during the early hours of the day (00 00 – 04 00hrs). Similar estimates were also been carried out on the biomass of Pelagic shrimps (Karuppasamy, 2001) and Photicthyidae (Vimala, 2002) from the Deep Scattering Layer of the west coast of India.

Summary

Summary

The present investigation was carried out on the leptocephali of the Deep Scattering Layer (DSL) of the south west coast of India. The aim of the study was to understand the distribution and abundance and also the major groups of leptocephali in space and time in the DSL. Samples for the study was collected between May 1998 to June 2001 onboard FORV Sagar Sampada. The salient features of the study are summarized as given below:

1. Samplings were carried out on 148 stations (81 night and 67 day) using IKMT on the west coast of India (6°-21° N latitude).
2. Specific area for study was the south west coast of India (6° to area below 15° N latitude)
3. In the west coast, the highest area of abundance (18.32 no/1000m^3) recorded from the area 12°30 N - 71°29 E.
4. Highest abundance (in tones) of leptocephali in the west coast recorded from area 19° N – 68° E (6481.88t)
5. Five major families viz. Congridae, Ophichthidae, Muraenidae, Nemichthyidae and Synaphobranchidae including 8genera, 2 species and a few other unidentified species.
6. Total biomass (no/1000m^3) of south west coast accounted to 35.85% of the west coast leptocephalid biomass.
7. Night catch of leptocephali formed 87% of the total catch in the south west coast and day 13%.
8. Congridae has the highest contribution (44%) closely followed by Ophichthidae (30%).
9. Maximum concentration of congrid leptocephali recorded between 9° and 10° N latitudes.
10. Diurnal variations show the maximum abundance of congrid leptocephali during late night hours (20 00 – 00 00 hours).
11. Vertical abundance of congrid leptocephali was maximum in the 50-100m range where as the horizontal abundance in 1000-3000m depth range.

12. The congrid leptocephali concentrated more, especially in the night, with in the 100m range.
13. Congrid leptocephali present to a maximum depth (depth of operation) of 420m.
14. Ophichthid leptocephali show maximum aggregation in the 12°N latitude.
15. Vertical abundance (depth of operation) of ophichthid leptocephali maximum at 50-100m depth and the abundance with respect to the depth of bottom was maximum in the zone of 1000-3000m.
16. Diurnal variation of ophichthid leptocephali was maximum during the early hours of the day between 04 00 – 08 00 hours.
17. Ophichthid leptocephali present to a maximum depth of 750m.
18. Muraenid leptocephali showed a slightly high abundance in 10°N latitude.
19. Vertically (depth of operation) the muraenid leptocephali were maximum in the 50-100m range where as horizontally (depth of bottom) it was at the 1000-3000m depth range.
20. Muraenid leptocephali were totally absent in 0-200m (depth of bottom) depth zone.
21. Diurnal abundance was maximum during the early hours of the day between 04 00 – 08 00 hours.
22. Muraenid leptocephali were present to a depth of 420m.
23. Nemichthyidae and Synaphobranchidae were abundant to a maximum depth of 380m and 400m, respectively.
24. Total leptocephalid biomass on the west coast was 76227.87 tones with a maximum recording at 19°N latitude, off Bombay (6481.88t).
25. Leptocephalid biomass (in tones) abundance was more prominent in the north west coast.
26. Nighttime leptocephalid biomass was more in comparison, on the north west coast of India.
27. Congrid biomass was maximum in 9°N latitude in the south west coast of India.

28. Vertical abundance of Congridae maximum in the 0-50m depth range (163.38t) and that of horizontal abundance in the 1000-3000m depth zone (266t).
29. Family Ophichthidae was abundant in the area off Mangalore (12°N latitude).
30. Vertical abundance of biomass (average) of Ophichthidae was maximum in the 50-100m depth range (285.18t).
31. An increase in the biomass (average) of Ophichthidae with an increase in the bottom depth was observed, with a maximum in the 1000-3000m mark (141.95t).
32. The muraenid biomass (average) was maximum in the 12°N latitude (64.63t).
33. Diurnal variations in the average biomass was higher (185.55t) between 00 00 – 04 00hours.

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STUDIES ON THE LEPTOCEPHALI OF DEEP SCATTERING LAYER (DSL) OF THE SOUTH WEST COAST OF INDIA

Thesis submitted to the

KARNATAK UNIVERSITY

in

partial fulfillment for the degree of

DOCTOR OF PHILOSOPHY

in

MARINE BIOLOGY

By

BALU.S

SCHOOL OF OCEAN SCIENCES

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CERTIFICATE

Certified that the thesis entitled **"Studies on the Leptocephali of Deep Scattering Layer (DSL) of the south west coast of India"** by **Mr. BALU.S** for the degree of **Doctor of Philosophy** in Marine Biology, Karnatak University, is a record of bonafide research work carried out by him under my supervision and guidance and that the thesis or a part there of has not formed the basis of any degree, diploma or any other similar title.

(KUSUMA NEELAKANTAN)
Supervising Teacher

DECLARATION

I here by declare that this thesis entitled **"Studies on the Leptocephali of Deep Scattering Layer (DSL) of the south west coast of India"** is an authentic record of work done by me and no part has been presented for award of any degree, diploma or other similar title.

(BALU.S)

Dedicated

to

My Beloved Parents

ACKNOWLEDGEMENT

*I express my deep sense of gratitude to my Supervising Teacher Dr. (Mrs.) **Kusuma Neelakantan,** Chairperson, School of Ocean Sciences, Karnatak University Post Graduate and Research Center, Karwar, for her guidance, invaluable suggestions and constant encouragement for the successful completion of the work.*

I am extremely grateful to the Late Professor, Dr. B. Neelakantan, former Chairman, School of Ocean Sciences, Karnatak University Post Graduate and Research Center Karwar, for his timely and unconditional help and encouragement.

I express my sincere gratitude to the present Director of C.M.F.R.I, Cochin, Dr. Mohan Joseph Modayil and former Directors of C.M.F.R.I, Dr. M. Devaraj, Dr. V.N.Pillai for providing the necessary facilities at the institute for my research work.

I deeply acknowledge the constant encouragement and invaluable suggestions and advices given by Dr. N.G. Menon, Principal Scientist and Principal Investigator of the DOD-DSL Project, C.M.F.R.I., Cochin, through out the period of study.

I place in record my sincere thanks to Dr. K. H. Mohamed for his keen interest in the subject and for critically going through the manuscript with valuable suggestions.

My sincere thanks are also due to Dr. U.G. Bhat, Reader and Mr. J.L.Rathod , Lecturer, both of the School of Ocean Sciences, Karnatak University Post Graduate and Research Center, Karwar, for their help and support.

I express my gratitude to Dr. R.S.Biradar, Principal Scientist and Controller of Examinations, C.I.F.E., Mumbai, for his timely action in processing and sending the migration certificate. I also thank Mrs. Arati Revankar for her generous help rendered for the processing of migration certificate at C.I.F.E, Mumbai and unconditional support.

I am extremely grateful to Dr. K.K.Joshi, Senior Scientist and Mr. K. Balachandran, Technical Officer, both of Demersal Fisheries Division of C.M.F.R.I., Cochin, for their unconditional help and support and for critically scrutinizing the manuscript with valuable suggestions.

It is my pleasure to acknowledge the kind of support and encouragement given by Dr. (Mrs.) L. PrabhaDevi, Lecturer, School of Advance Life Sciences of M.G. University, Pathanamthitta, Dr. A. A. Jayaprakash, Principal Scientist, Pelagic Fisheries Division of C.M.F.R.I., Cochin; Dr.K.K.Appukuttan, Principal Scientist and Head, Dr. (Mrs) V.Kripa and Dr. P.Laxmilatha, Senior Scientists, Dr. (Mrs.) Shoji Joseph, Scientist, Mr. Mathew Joseph and Mrs. Jenni Sharma, Technical Officers, all of the Molluscan Fisheries Division of C.M.F.R.I., Cochin; Dr. George J.P, Principal Scientist, Fisheries Environment Management Division and Mrs. Rekha J. Nair, Scientist, Demersal Fisheries Division, both of C.M.F.R.I., Cochin, Mr. V. Edwin Joseph, Technical Officer (Librarian), C.M.F.R.I., Cochin and Dr. A. Gopalakrishnan, Senior Scientist of the N.B.F.G.R., Cochin.

I express my sincere thanks to Ms. Sherri Charter, Research Fishery Biologist, NMFS, South west Fisheries Science Center, La Jolla, California, U.S.A, for her subject expertise, valuable suggestions and for providing important references with out hesitation and delay, as and when requested. I also thank Ms. Rosalie Shaffer, Technical Information Specialist of the NMFS, Panama City Laboratory Library, Florida, U.S.A. for the quick response to my requests for references.

It is with great pleasure I would thank Dr. Satish Sahayak, Project Scientist, Regional Center of N.I.O, Cochin, for his technical excellence in photography and unconditional help. I also thank Mr. K.K. Shankaran, Artist, C.M.F.R.I., Cochin, for his artistical capabilities in making the graphs and maps.

I express my gratitude to all my friends and colleagues for their unfailing help and support during various stages of my study with special mention to Dr. Manoj Nair. R; Dr. F. G. Benno Ferreira and Dr. G. Prasad, both Lecturers of St. Albert's College, Cochin; Dr. P. K. Karuppasamy, Project Scientist, Regional Center of N.I.O, Cochin; Dr. Vimala P.T, *Mrs. Simmy George, Dr. Soniraj N, Dr. Anilkumar P.K, Dr. Girish R, Dr. and Mrs. Rammohan, Dr. Seema Khot, Mr. Rajesh B, Mr. Baiju S, Mr. Manoj B. Dethan, Mr. Unnikrishnan. U, Dr. Abraham K.J, and Mrs. Anikumari, Miss. Anjana Mohan, Miss. Jugnu R, Miss. Sreejaya R, Mr. Ramalinga, Mr. M. Vinod, Mr. P.S .Alloycious and Mr. M.N .Satyan of the Molluscan Fisheries Division, C.M.F.R.I., Cochin.*

I wish to express my thanks to the Department of Ocean Development, Govt. of India, New Delhi, for providing the leptocephali collection of FORV Sagar Sampada from the west coast at my disposal and for granting me Senior Research Fellowship with out which the present study was not possible. With much gratitude I extend my sincere thanks to Dr. V. Ravindranathan, Advisor, Dr. V.N. Sanjeevan, Principal Scientific Officer and other staff of C.M.L.R.E of DOD, Cochin, for their kind cooperation and timely help. My thanks are also due to the Officers and crew of S.C.I; Fishing Masters and Fishing Hands of DOD and the Service Engineers of NORINCO on board FORV Sagar Sampada for their help and cooperation rendered during the cruises.

Lastly, it is my pleasure to express my gratitude to my Parents, Brother and family and to my Wife for their love, support and constant encouragement through out the period of study.

Contents

Introduction

Introduction

The waters of the World Ocean, from the surface to the deepest reaches of the bottom trenches, have a total volume of about 1.4 million cubic kilometeres, more than 99% of Earth's biosphere. One of the most important discoveries of early oceanographic expeditions was the great variety of deep ocean life, well adapted to pressure and cold. Since then, sampling with trawl nets and more recently with acoustics and submersibles has increased our understanding of the under water fauna, but it remains one of the least explored environments on earth. This vast habitat is home to far fewer species than any terrestrial or near shore marine environment.

The mid-water can be divided into two major regions ie. mesopelagic and bathy pelagic - based on depth, with very different physical and biological attributes. The mesopelagic zone (200-1000 m), is a twilight region where sunlight is too weak to support photosynthesis, but penetrates sufficiently to affect the behaviour of animals, on a diurnal schedule, that is, the animals living there can see and react to the changing light levels and the bathypelagic zone (>1000 m), accounting for 88 % of the total Ocean area and covering the entire deep ocean floor where there is no light, the temperature is cold and constant and food is scarce. The proximity of upper water primary production makes it possible for many herbivores to live in the mesopelagic zone and perhaps half the species are vertical migrators who spend the day at depth but come to the rich surface waters at night to feed on phytoplankton or other animals. The general pattern of daily or diurnal vertical migration has been deduced from numerous sources of information. Net collections of animals from several depths at different times throughout the day have shown that more animals are near the surface at night. Under water sound pulses from ship mounted echo sounders have also been used extensively to study the behaviour of vertically migrating animals. These pulses are partially reflected by the concentration or layers of mid-water animals and appear as a "false bottom" on the echogram. These diurnally, vertically moving bio acoustic layers or "false bottoms" are called Deep Scattering Layers (DSL) or Sound Scattering Layers (SSL).

The existence of "deep scattering layer" in the Ocean was discovered by Eyring, Christensen and Raitt during 1942 while working for the University of California, Division of War Research. The wide spread occurrence of deep scattering layers in world oceans and their rich bio-composition aroused scientific interest ever since their discovery (Duvall and Christensen, 1946; Eyring *et al.*,1948 and Raitt, 1948).

The DSL is an important ecosystem of world oceans and supports a wide assemblage of zooplankton, micro and macro nekton. The bio-composition of the deep scattering layers of the world ocean has been well described by Marshall (1951), Tucker (1951), Barham (1957), Pearcy and Laurs (1966), Taylor (1968), Kinzer (1969), and Silas (1972) showed the predominance of macroplankton and micro nekton in the DSL. The above studies also indicated the occurrence of a wide assemblage of young or adults of epipelagic, mesopelagic and to a lesser extent bathypelagic fishes. The availability, abundance and vertical migration of these fishes are influenced or controlled by the occurrence and quantity of favourite food components of DSL.

In spite of a rather rich literature available on the DSL of many parts of the world oceans (Anon, 1946; Dietz, 1948; Raitt, 1948; Boden, 1950, 1962; Moore, 1950; Hersey *et al.*, 1952; Bernard, 1955; Uda, 1956; Backus and Barnes, 1957; Clarke and Backus; 1964; Barham, 1966; Barry, 1966a,b; Kinzer, 1969), the Indian Ocean, particularly the Indian Seas remained the least investigated for the DSL. The information available for the Indian Ocean is those of Daniel *et al.* (1969), Silas (1972), Menon (1990), Menon and Prabha Devi (1990), James and Prabha Devi (1990), Mini Raman and James (1990), Mathew and Natarajan (1990), Balasubramaian and Suseelan (1990) and Suseelan and Manmadan Nair (1990). A preliminary study of the zoological constituents of the sonic scattering layer was made by Daniel *et al.* (1969) based on observations made at seven stations in the Bay of Bengal. Silas (1972) made some valuable studies on the DSL in the Lakshadweep

Sea and Menon (1990) investigated on the fish biomass in the Deep Scattering Layers of the EEZ of India. In their investigations on the various aspects of Deep Scattering Layer of Indian EEZ, Menon and Prabha Devi (1990) studied the total biomass, James and Prabha Devi (1990) on the leptocephali, Mini Raman and James (1990) on the Myctophids, Mathew and Natarajan (1990) on the Euphausiid component, Suseelan and Manmadan Nair (1990) on Pelagic Shrimps and Balasubramanian and Suseelan (1990) on the swarming crabs.

Studies carried out on the biomass of the Deep Scattering Layer of the Indian EEZ during the cruises of FORV Sagar Sampada (1985-1987) revealed that 94% of the total biomass was composed of plankton and 6% by micro and macro nekton. The micro nekton was represented by Euphausiids, Decapods, Siphonophores, Copepods, Pteropods, Heteropods, Amphipods, Ostracods, Chaetognaths, Larval Crustaceans and the macronekton by a concentration of fishes of families like Myctophidae, Gonostomatidae, Photichthyidae, Bregmacerotidae and Leptocephali and juveniles of several other families of fishes. Among the macro-nekton, Leptocephali formed one of the most important groups of the DSL biomass. It constituted about 7.5% of the total fish biomass in the DSL of the EEZ of India (Menon, 1990).

Leptocephali, the larval forms of eels are distinctive among larval fishes (Smith, 1989 a; Hulet and Robins, 1989). A small, thin, laterally compressed head gives the leptocephalus its name (leptocephalus = "slender head"). Their body is laterally compressed, largely shaped by a gelatinous material surrounded by a thin layer of myotomal muscle ('V' or 'W' shaped), have a simple gut and are nearly transparent. They possess well-developed eyes, olfactory organs and have a series of strong, fang like, forwardly directed teeth. The Leptocephalus stage lasts for months to years, and grow to a large size for larval fishes, typically 50-100 mm (Bohlke, 1989 b), but much more in some species (Smith, 1989 b-d), before metamorphosing into elvers. A pelagic, long-lived Leptocephalus is common to the families of eels, whether the juveniles inhabit the open ocean, shelf waters or estuarine and fresh waters. They inhabit the upper few hundred meters of the water column throughout the world oceans, primarily in tropical and sub tropical areas. Although leptocephalus is a larval type shared by the Elopiform, Saccopharyngiform and Notacanthiform fishes, the largest groups of fishes with this type of larva are the eels of the order Angulliformes. Leptocephali in the DSL were mainly represented by the families of the order Angulliformes viz.,Congridae, Muraenidae, Muraenesocidae, Synaphobranchidae, Nettastomatidae, Nemichthyidae, Ophichthyidae etc. Leptocephali of the order Elopiformes were also represented in few instances.

The study on the development of the eel has been made classic by the wonderful researches of Schmidt (1922a, 1923a, 1924d, 1925), that the European eel *Anguilla anguilla* and the American eel *Anguilla rostrata* grow in European and American rivers and go down to the Atlantic and returned as elvers after a prolonged larval period as leptocephali, has been well established. Very little, however is known regarding the breeding of the Indian freshwater eels such as *Anguilla bengalensis* and *Anguilla bicolor* except for scattered references of their occurrence in some Indian rivers. Similarly very little literature is available about the breeding habits of the Indian marine eels, such as, *Muraenesox cinereus, Muraenesox talabon, Muraenesox talabonoides* (Family Muraenesocidae) *Uroconger lepturus* (Family Congridae), eels of the families Ophichthidae, Muraenidae etc.

As the food from the land is so limited that it may not be able to satisfy even the basic requirements of the ever increasing human population, an alternative to over come this problem is to tap the vast unexploited resources of the ocean which could nourish the population many times more than its present level. Eel is one such resource and is considered as a luxury food and consumed in delicacy by Greeks, Romans, Japanese and people of several Asian and European countries. Even though it is considered as a food fish in India their exploitation is limited. But their export demands offers scope for culture and live transport to foreign markets, besides increasing their exploitation from all along the distributional range.

Very few workers have focussed their attention to study the systematics of the leptocephalus larvae. Much work has been published on the anguillid leptocephali of the temperate and sub-tropical regions. Several cruises were also conducted to locate the breeding grounds of the American and European eels in relation to water masses and other oceanographic features (Kleckner and Mc Cleave, 1985; Mc Cleave and Kleckner, 1987; Castonguay and Mc Cleave, 1987). Karmovskaya (1986) worked out in detail the identification of leptocephali of Angulliformes based on the collection from the world oceans. But no such studies have been carried out along the seas of Indian subcontinent so far, except for some scattered reports. Most of the work from India was concentrated on the study of metamorphosis of leptocephali and also identifying and relating them to their respective adults. (Aiyar *et al.* (1944), Bapat (1955), Gopinath (1946,1950), James and Prabhadevi (1990), Jones and Pantulu (1952,1955), Nair (1946, 1947,1948), Nair and Bhimachar (1950), Nair and Mohamed (1960 a,b,c,d,e) and Pantulu and Jones (1954)). Some studies were also carried out on the eel eggs and their development (Aiyar *et al.*, 1944; Nair and Bhimachar, 1950; Bapat, 1955; Nair and Dharmamba, 1960; Ganapati and Raju, 1960, 1963; Bensam, 1966; Rani Mary George, 1987).

In view of the scanty records of Indian leptocephali, a thorough and systematic study of these larvae together with a knowledge of their distribution is an important and necessary prelude to the study of the biology of the Indian eels, of which we know so little while great advances have been made in the study of their European counterpart. In the present study an attempt is made to evaluate the distribution and abundance of Anguilliform leptocephali in space and time and also to study their metamorphosis in order to estimate their resource potential. Samples for the study were collected during the cruises of FORV Sagar Sampada from 1998-2001 as part of the Department of Ocean Development (DOD), Govt. of India, funded project "Studies on Deep Scattering Layer". The commissioning of the research vessel FORV Sagar Sampada for resource surveys in the Indian EEZ and contiguous water was a milestone in the history of fisheries research, which gave an excellent opportunity to make a comprehensive study on this subject.

Material and methods

Material and methods

The material for the present study was collected from the cruises of FORV *Sagar Sampada* (Fig.1) along the west coast of India (64° - 77°E longitude; 6° - 21°N latitude) during May 1998 to June 2001. Details of the cruise tracks, station positions, depth, time, duration of gear operation and other operational details were collected from the cruise reports of FORV *Sagar Sampada* covering the area of investigation.

Samplings on the Deep Scattering Layer (DSL) were carried out using two types of gears – Isaacs - Kidd Midwater Trawl (IKMT) and Midwater Trawl. IKMT is a specifically designed gear to collect meso and bathy pelagic specimens larger and more active than the plankton taken by standard plankton nets. The Isaacs - Kidd Midwater Trawl (IKMT) (Fig.2) was originally conceived and developed by John D. Isaacs and Lewis W. Kidd (1951) of the University of California's Scripp's Institution of Oceanography. It consists essentially of a net made of nylon attached to a 'V'- shaped rigid, aluminum depressor. The IKMT on board FORV *Sagar Sampada* is made of nylon webbing with four sections of different mesh sizes of 25mm, 16mm, 11mm, and 5mm and length of 500mm, 500mm, 8250mm, and 1750mm, respectively, totaling 11m. The width tapered from 2500m to 750mm, from the mouth opening to the cod end. The 'V'- shaped aluminium depressor weighing 25kg and 2.5m length is attached to the mouth opening in order to maintain the proper opening of the net at a predetermined depth of operation. A five litre capacity bucket is attached to the cod end where the sample gets collected. IKMT was operated on the basis of DSL recordings in the echo sounders (38K Hz and 120 K Hz). It was operated to a maximum depth of 750m during the present study. Samples for the present study was mainly from IKMT.

IKMT was mainly operated on the principal layer and also on all layers, wherever multi layered DSL were sighted. The towing speed of ship was maintained between 3 – 4 knots for a period of 30 minutes. The sample collected was first washed in seawater and then the total volume taken using a standard measuring cylinder. It was then filtered and preserved in 5% formalin with proper labeling. In

Fig. 1. FORV Sagar Sampada

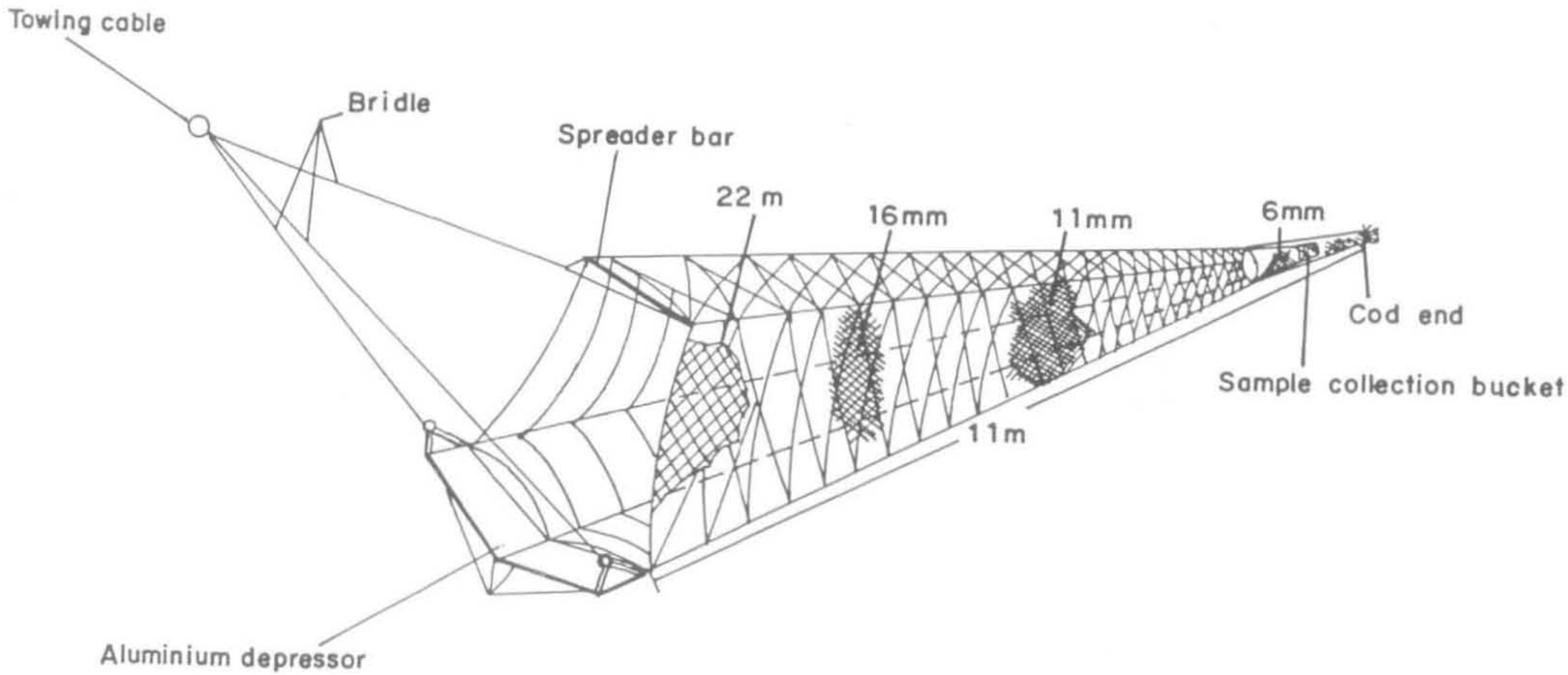


Fig: 2. Rigging of Isaacs-Kidd Midwater Trawl the shore laboratory the samples were analyzed for systematic studies, distribution, biomass estimation and for studying the metamorphosing stages.

The literature on the Indian leptocephali were scanty, except for some scattered works by Aiyar et al. (1944), Panikkar and Nair (1945), Gopinath (1946, 1950), Nair (1946, 1947, 1948, 1960), Nair and Bhimachar (1950), Johns and Pantulu (1952, 1955), Pantulu and Jones (1954) Nair and Dharmamba (1960), Nair and Mohamed (1960 a - e) Ganapati and Raju (1961), etc., the identification of leptocephali to family level and in some cases down to genus and species level, were carried out mainly with the key formulated by Smith (1979). For the systematic studies a total of 23 characters (morpho metric and merisrtic) were taken onto consideration, as given below:

Morphometric Characters	**Meristic Characters**
Total length	Total Myomeres
Standard length	Anal Opening
Maximum Height (excluding fins)	Pre anal Myomeres
Length of Head	Post anal Myomeres
Length of Upper Jaw	Origin of Dorsal fin
Length of Lower Jaw	Dorsal fin Rays
Length of Snout	Anal fin Rays
Diameter of Eye	Caudal fin Rays
Position of Nasal Pit	Teeth in Upper Jaw
Position of First Nostril	Teeth in Lower Jaw
Size of First Nostril	
Position of Second Nostril	
Size of Second Nostril	

Due to its mucilaginous nature, weights of the leptocephali were not taken into consideration.

Length measurements and maximum body height were taken using a standard measuring board. In case of specimens with a damaged caudal fin, only standard length was taken. Length of head was taken using a divider. Other measurements like length of upper and lower jaws, snout; diameter of eye; position of nasal pit, first and second nostrils and size of first and second nostrils were taken using an ocular micrometer (Erma Inc., Japan) calibrated to the nearest millimeter in a compound microscope (Getner). The meristic measurements include total, pre and post anal myomeres; dorsal, anal and caudal fin rays; teeth on upper and lower jaws etc. Counting of the myomeres and teeth were done using a stereo zoom microscope (Ceti, Belgium). Positions of anus and dorsal fin origin were ascertained with the corresponding myomeres, so it was also included in the meristic counts. The morphometric measurements taken are given in Fig.3.

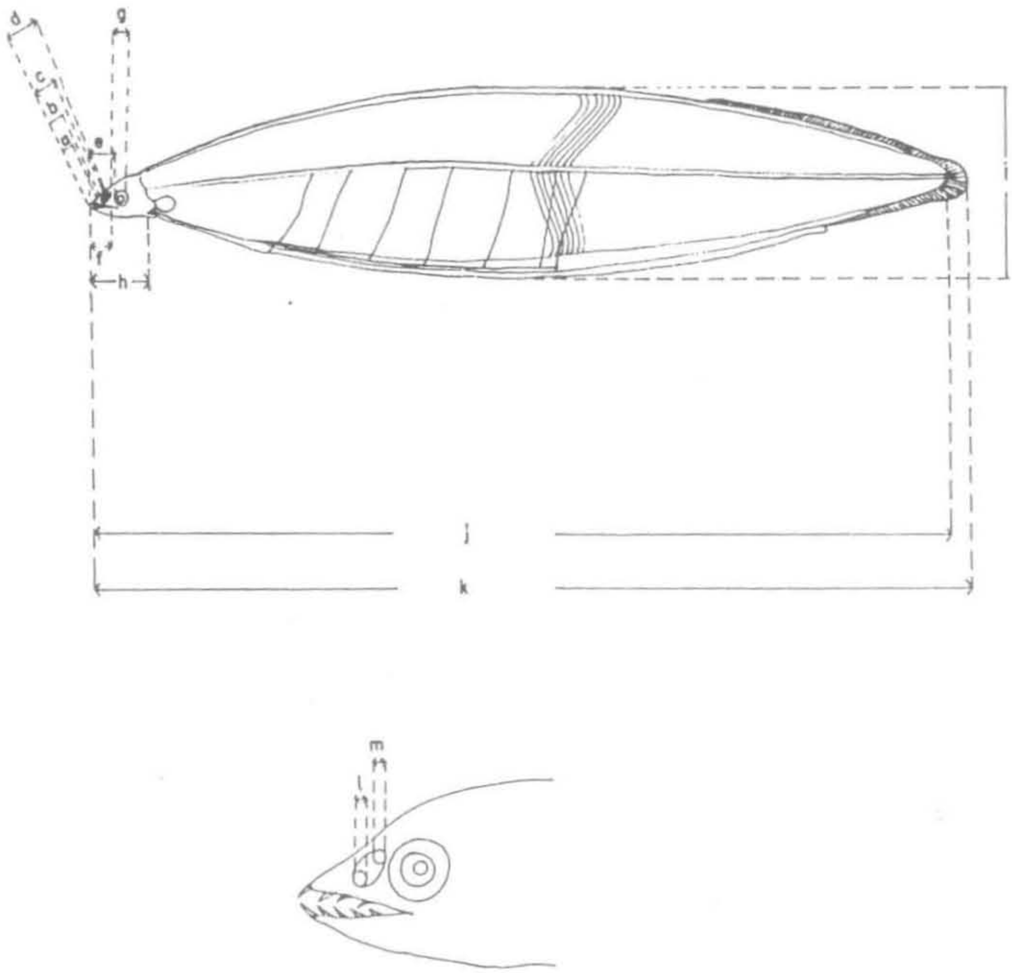
Pigmentation on leptocephali formed an important character for identification with its presence along the alimentary canal, head, body, fins etc. Another important character was the loops or swellings on the intestine, especially in the identification of Ophichthidae.

For the estimation in no/1000m^3, first the volume of water filtered is calculated from the area of the net and the area swept in 30minutes. From this the no/1000m^3 is found out for every counted sample from each station

$$\text{ie. no/1000m}^3 = \frac{\text{no*1000}}{\text{Vol. of water filtered}}$$

This is then converted into biomass in tones (t) in 1° square by taking into consideration the area of 1° square and the DSL thickness (in meters) for the respective stations.

Biomass in tones (t) in 1° square = no/1000m^3 * area of 1° square* DSL thickness



a . Position of nasal pit
b . Position of first nostril
c . Position of second nostril
d . Length of snout
e . Length of upper jaw
f . Length of lower jaw
g . Diameter of eye
h . Length of head

i . Maximum body height (excluding fins)
j . Standard Length
k . Total length
l . Size of first nostril
m . Size of second nostril

Fig : 3 Leptocephalus – Morphometric measurements

Systematics

The first leptocephalus of record was collected in or shortly before 1763 by William Morris on the north coast of Wales. Gronow (1763) published the first description and gave it the name "Leptocephalus" though his work was later rejected for nomenclature purposes. For the next century, Leptocephali were treated as a distinct group of fishes. As new species were discovered they were placed either with in the genus *Leptocephalus* or into new genera. In 1861, Carus (1861a) mentioned about the small group of translucent fishes without reproductive organs, known especially from the Straits of Messina and generally called *Leptocephalidae*. He also set forth the theory that the leptocephalids were not adult fishes, but larval stages of other species, but was not able to refer them to definite adults. Gill (1864), was the first to suggest that the leptocephals were the larvae of eels ("Congers"), but the scientific proof was not given until Dareste (1873 b), showed that the so-called *Leptocephalus splanzani (= L. morrisii)* was a larval form of *Conger vulgaris*. Delage (1886) succeeded in keeping a Leptocephal alive in an aquarium so long that it metamorphosed into a young conger, thus proving that the Leptocephals are the larval stages of eel. Grassi and Calandruccio (1893), continued the experiments with other Leptocephals and proved with certainty that *Leptocephalus brevirostris*, described by Kaup (1856b), was the larval form of European fresh water eel, *Anguilla anguilla*,L.

General Description of Leptocephalus

Leptocephali are among the most distinctive of all larval fishes. They have an elongate, highly compressed, nearly transparent body with a series of 'V' or 'W' shaped myomeres covering most of the lateral surface (Fig.4). A transparent area extends dorsally and ventrally from the myomeres. They possess a small, laterally compressed head (hence the name leptocephalus = "slender head") with a series of strong, fang like, forwardly inclined teeth present on both upper and lower jaws. Dorsal, anal and pectoral fins are present in all leptocephali. In Anguilliformes, the dorsal and anal fins are long and continuous with a small, round caudal fin. Elopiform leptocephali have a large, forked caudal fin separate from the dorsal and

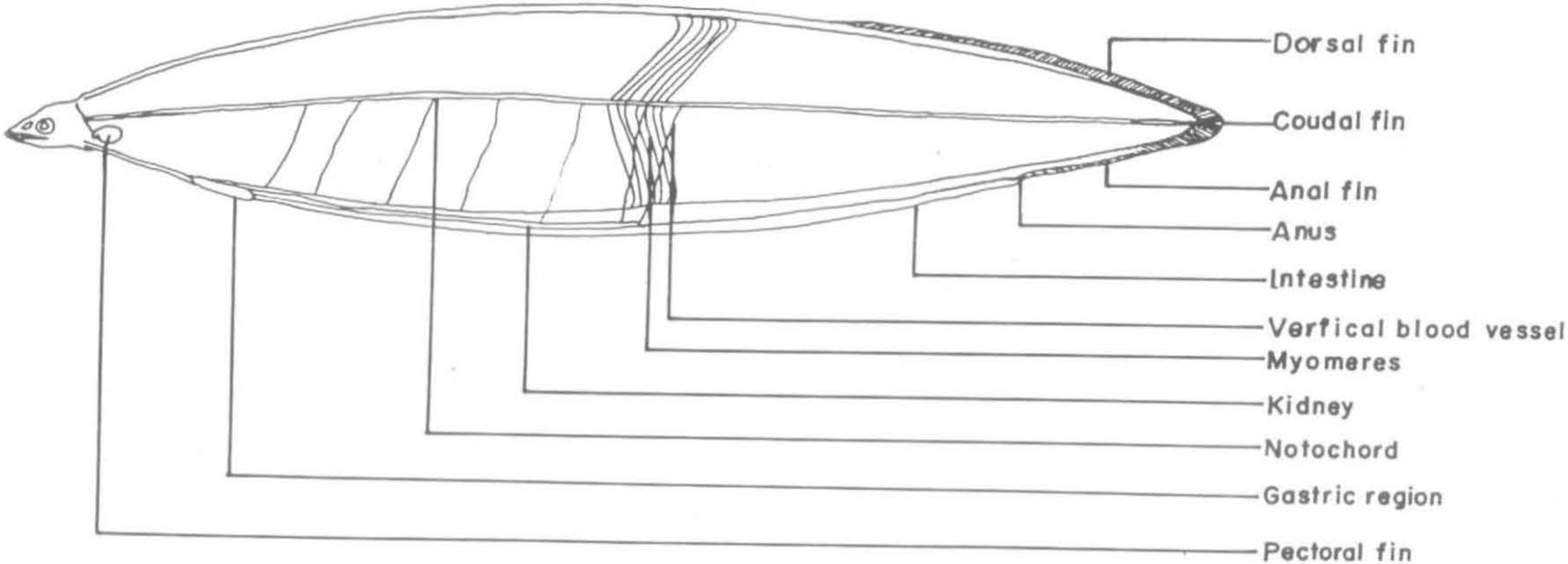


Fig. 4. Leptocephali – Body parts

anal fins and in the Notacanthiform, leptocephali it is in the form of a single filament. Hypural plates are present in all leptocephali, well before metamorphosis.

Most of the interior of the body is filled with an acellular mucinous material bounded by a continuous layer of epithelial cells. The mucinous pouch is the most characteristic feature of the leptocephalus. It separates the viscera, the notochord and the two sides of the body musculature from each other and gives form and rigidity to the body. The myomeres are thin and the skin is only a few cell layers in thickness.

The gut lies in the ventral margin. It is in the form of a simple, straight tube or may have swellings, arches or looped. The stomach is a rudimentary diverticulum at the point where the oesophagus and intestine meet. The liver and gall bladder are located near the same point. Liver may some times be extensive and divided into more than one lobe. The kidney (nephros) is a linear structure lying along the top of the gut. Gill arches are present but filaments do not appear until later in development.

The notochord runs through the middle of the body with the spinal cord lying above it and the dorsal aorta below. A series of vertical blood vessels extend between the dorsal aorta and the viscera, the posterior most entering the posterior end of the kidney. The heart is located beneath the anterior end of the oesophagus and in front of the pectoral fin. Although heart and blood vessels are present and functional, no haemoglobin is formed until metamorphosis. The eyes, olfactory organs and the portions of brain associated with them are well developed.

Living leptocephali are completely transparent except for the pigmentation on eye and body. Pigmentation is present in the form of melanophores. Melanin is present in the choroids of eye and in discrete melanophores distributed in characteristic patterns on head and body. A few leptocephali lack melanophores, but most have at least some.

One of the striking features of leptocephali is their large size. Lengths of 50 – 100 mm are common and some forms (Notacanthiformes (Nielsen and Larsen,

1970)) grow even much larger (1800 mm). They grow larger before metamorphosing than most other larval fishes. At metamorphosis, the leptocephalus shrinks, as the mucinous filler is lost.

World wide, leptocephali of Angulliform eels belonging to 16 families have been recognised so far, with many more unidentified leptocephali remaining. Smith (1979), published an exclusive guide with key, on the identification of leptocephali belonging to the three orders viz. Elopiformes, Anguilliformes and Notacanthiformes from the world oceans. The key is according to Smith (1979).

Key to Families

A1 Eye telescopic...B (Synaphobranchidae)
A2 Eye normal...C

B1 Intestinal pigment present; gut with several small thickenings; rostral filament sometimes present...Dysominae
B2 Intestinal pigment absent; gut a simple straight tube; rostral filament absent...Synaphobranchinae

C1 Head deep with elongate hyomandibula; gut with a single pigmented thickening at posterior end.....................................Saccopharyngoidei
C2 Head and jaw suspension normal...D

D1 Gut with one or more thickenings, loops or arches...............................E
D2 Gut a simple straight tube without thickenings, loops or arches................H

E1 Gut with a single thickening or arch at posterior end...............Moringuidae
E2 Gut with two or more thickenings or arches..F

F1 Gut with two thickenings.................................Nettastomatidae (Part)
F2 Gut with three or more thickenings or arches....................................G

G1 Body very deep; myomeres about 80...................................Cyemidae
G2 Body moderately elongate; myomeres more than 100.............Ophichthidae

H1 Melanophores absent...Anguillidae
H2 At least some melanophores present..I

I1 Intestinal pigment absent..J
I2 Intestinal pigment present...L

J1 Pectoral fin greatly reduced; gut less than half standard length; dorsal and anal fin restricted to tip of caudal fin.......Muraenidae (in part: *Anarchias*)

J2 Pectoral fin well developed; gut more than half standard length; dorsal and anal fins not restricted to posterior tip of body..............................K

K1 Last vertical blood vessel around myomeres 70-80; preanal myomeres more than 100..................................Derichthyidae: *Nessorhamphus*

K2 Last vertical blood vessel at myomeres 59-63; preanal myomeres 76-83..Derichthyidae: *Dericthys*

K3 Last vertical blood vessel at myomeres 30-37; preanal myomeres 89-125...Serrivomeridae

L1 Pectoral fin greatly reduced; posterior nostril above level of middle of eye; tail generally broadly rounded.......................................Muraenidae

L2 Pectoral fin well developed; posterior nostril near or below level of middle eye; tail generally not broadly rounded..M

M1 Small but distinct deep-lying pigment spots along top of notochord; body elongate; ventral melanophores small, restricted to top of gut...Nemichthyidae

M2 Not as above ....N

N1 Gut half standard length or less..O

N2 Gut greater than half standard length..P

O1 Body narrow and elongate; head elongate..Nettastomatidae(in part: *Facciolella*)

O2 Body moderately deep; head moderately short...................Xenocongrudae

P1 Head short and deep; no crescentic patch of pigment below eye...Heterenchelyidae

P2 Head generally moderately elongate, snout more or less acute; those with short heads generally have crescentic patch of pigment below eye...Congridae (including Muraenesocidae)

In the present study, leptocephali belonging to five families viz. Congridae, Muraenidae, Nemichthyidae, Ophichthidae and Synaphobranchidae of the order Angulliformes have been identified up to genus and species level.

The Indian works are mostly from the collections made from the coastal waters and the present study being done on deep-sea collections, Lat. $6^0 - 14^0$ N, Long. $67^0 - 77^0$E and bottom depth 180 – 4600m, from the southwest coast of India. (Aiyar *et al*., 1944; Nair, 1946, 1947,1948; Gopinath 1946,1950; Nair and Bhimachar, 1950; Jones and Pantulu, 1952, 1955; Pantulu and Jones, 1954; Nair and

Mohamed, 1960 a- e). Since the work done on Indian leptocephali is scarce some of the genus has been tentatively identified based on the number of vertebrae.

The descriptions on the leptocephali of the five families are presented.

Family - Congridae

This is one among the largest of the eel families having wide variations in almost all important characters. The congrid leptocephali can be recognised from the following characters: body moderate to elongate; head and snout moderately short to moderately elongate; tail variable from very long to very short; ventral pigment variable but always present; lateral pigment variable, some times absent; maximum size variable, about 90 – 300mm in some species, most species probably reach close to 100mm.

***Ariosoma* type – Exterilium larva**

Specimens examined = 37; total length = 40-192mm; maximum body height (excluding vertical fins) = 15mm; length of head = 6mm; length of snout = 2.04mm; diameter of eye = 1.47mm; position of nasal pit = 1.38mm; position of first nostril = 1.41mm; size of first nostril = 0.16mm; position of second nostril = 1.86mm; size of second nostril = 0.19mm; total myomeres = 140-146; pre anal myomeres = 137; post anal myomeres = 7; origin of dorsal fin = 132nd myomere; dorsal fin rays = 44; anal fin rays = 42; caudal fin rays = 6+3; teeth = I+I+6+21 / I+9+9.

Moderate large leptocephali with long, broadly compressed body tapering to both ends; head moderately large (Plate1. a); snout bluntly pointed, with a concave constriction near the nasal organ; cleft of mouth straight, slightly oblique, reaching just near the centre of the eye; nasal region well developed with anterior and posterior nostrils separate; eye large and circular; larva with well defined dentition on each of its jaws (Plate1. b): the each half of upper jaw is provided with a short, antero-dorsal tooth above the long curved fang like grasping tooth followed by six large, pointed teeth and 21 closely arranged small teeth; lower jaw on its each half with a slightly curved, pointed grasping tooth, followed by nine large teeth and nine forwardly curved small teeth; pectoral fin oval with poorly developed rays; dorsal and anal fins restricted to the posterior with well defined rays, posterior most rays larger in comparison with the anterior ones; origin of dorsal fin slightly ahead of the anal fin origin; caudal fin with 9 well developed long rays on the two distinct hypurals (Plate1. e); intestine, long straight without loops or swellings, reaching to more than 3/4th of the body length and also trailing outside the body, outer part of which accounting for more than half the length of body.

Head of the larva with out any pigmentation; no pigmentation below eye; a few, scattered, stellate melanophores in and around the heart region; a mid dorsal row of scattered, stellate chromatophores starting from the 14th myomere continuing posteriorly where it becomes more scattered and discontinuous well before the dorsal fin origin; lateral pigmentation in the form of closely packed, small, stellate chromatophores (numbering 2 to as many as 23) forming oblique lines outlining the myosepta (Plate1. c), starting from the 7th myosepta and continuing till the last; a row of scattered, stellate chromatophores commencing from a region below the pectoral fin base on the ventral side of the gut anterior to the gastric region after which it becomes paired and switches over to the dorsal side of the intestine (Plate1. d) continuing till the tip of the outer intestine; all fin rays with pigments on its base except for a few anterior most dorsal and anal fin rays; no pigmentation on pectoral fin.

***Congrellus anago* (non Temm. and Schleg.)**

Specimens examined = 21; total length = 90-157mm; maximum height (excluding vertical fins) = 13mm; length of head = 4mm; length of snout = 1.22mm; diameter of eye =1.12mm; position of nasal pit = 0.70mm; position of first nostril = 0.74mm; size of first nostril = 0.1mm; position of second nostril = 1.02mm; size of second nostril; total myomeres = 112-118; pre anal myomeres = 106; post anal myomeres = 12; origin of dorsal fin = 106th myomere; dorsal fin

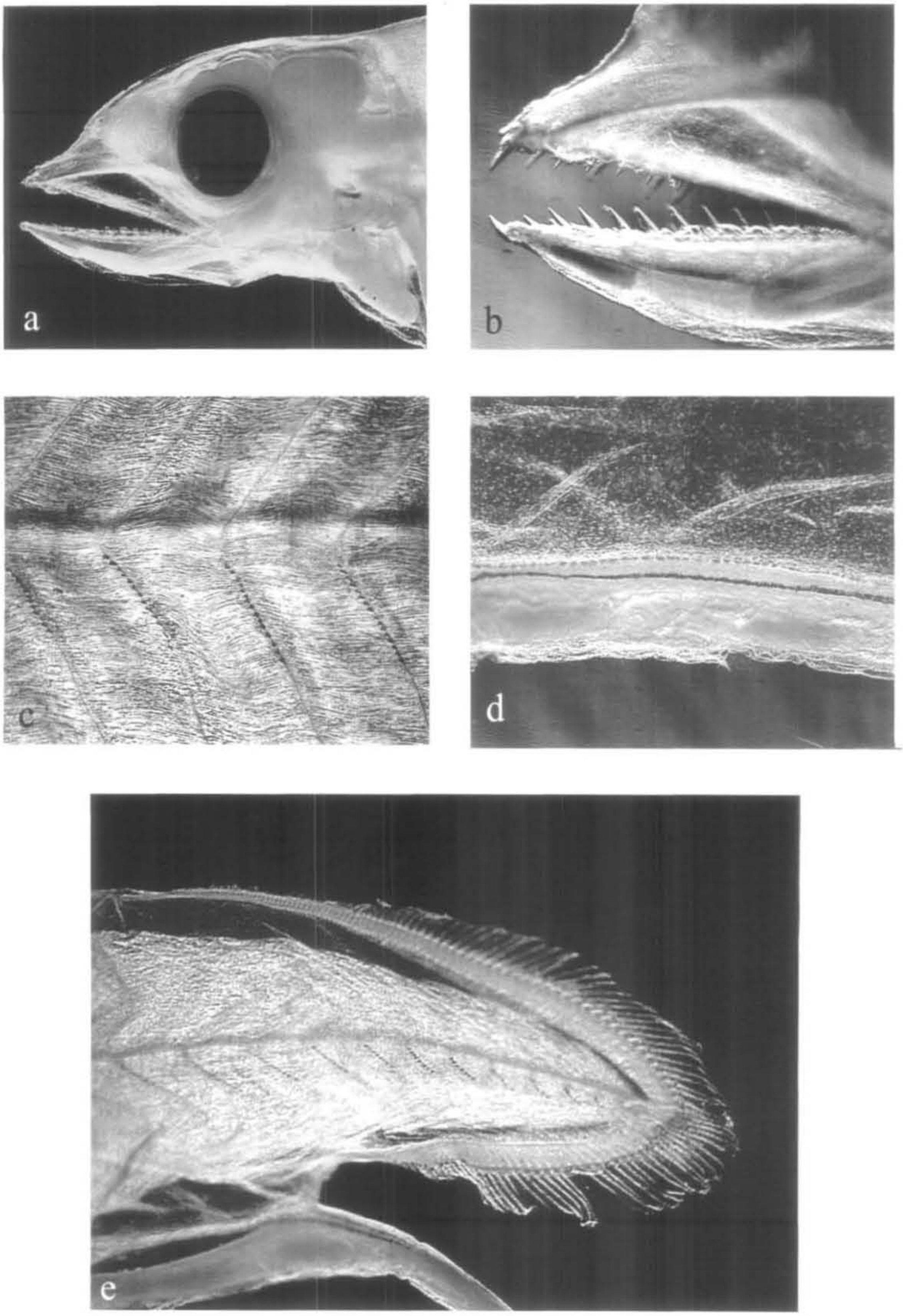


PLATE 1. Congridae - *Ariosoma* type - Exterillium larva
a. Head b. Teeth c. Lateral pigmentation
d. Pigmentation on dorsal side of intestine
e. Tail

rays = 47; anal fin rays = 50; caudal fin rays = 3+3; teeth = I+10+8 / I+10+4.

Body long, flattened, relatively broad and slightly tapering towards head and tail; head small (Plate2. a); snout triangular and bluntly pointed; cleft of mouth oblique, slightly curved, reaching up to the middle of eye; nasal organ developed with well differentiated nostrils; both jaws of the same length; prominent, large, circular eye; dentition very prominent on each half of both the jaws (Plate2. b): tip of upper jaw with a very prominent, sharply pointed tooth, ten large teeth decreasing in length anteriorly and posteriorly with the third tooth being the longest followed by 8 small closely packed teeth; in the lower jaw single curved tooth arising from just below the tip followed by ten large teeth and four small teeth; pectoral fin small, round with feeble rays; both dorsal and anal fins are restricted to the posterior with same level of origin (Plate2. f); posterior most rays of dorsal and anal fins longer in comparison with the anterior ones; caudal fin with six long and distinct rays; hypurals well developed; intestine long; straight, more than 3/4th length of body, opening at 106th myomere.

Head devoid of any pigmentation; a few scattered; stellate chromatophores beneath the heart (Plate2. c); a mid dorsal row of stellate chromatophores starting from 13th myomere, continuing posteriorly and become discontinued a distance before the origin of dorsal fin; lateral pigmentation in the form of a row of minute pigments numbering 3 to as many as 21, outlining the myosepta, starting from the 13th myosepta onwards to the last, giving the appearance of short, oblique lines (Plate2. d); a row of closely packed, stellate chromatophores on the ventral side of gut anterior to the gastric region, posterior to which it shifts to the dorsal side of the intestine (Plate2. e) and continuing till the anus; pigmentation on the base of all caudal fin rays and anal fin rays, except for a few anterior most anal fin rays; dorsal fin with pigmentation only on the base of posterior most long fin rays; pectoral fin with out pigmentation.

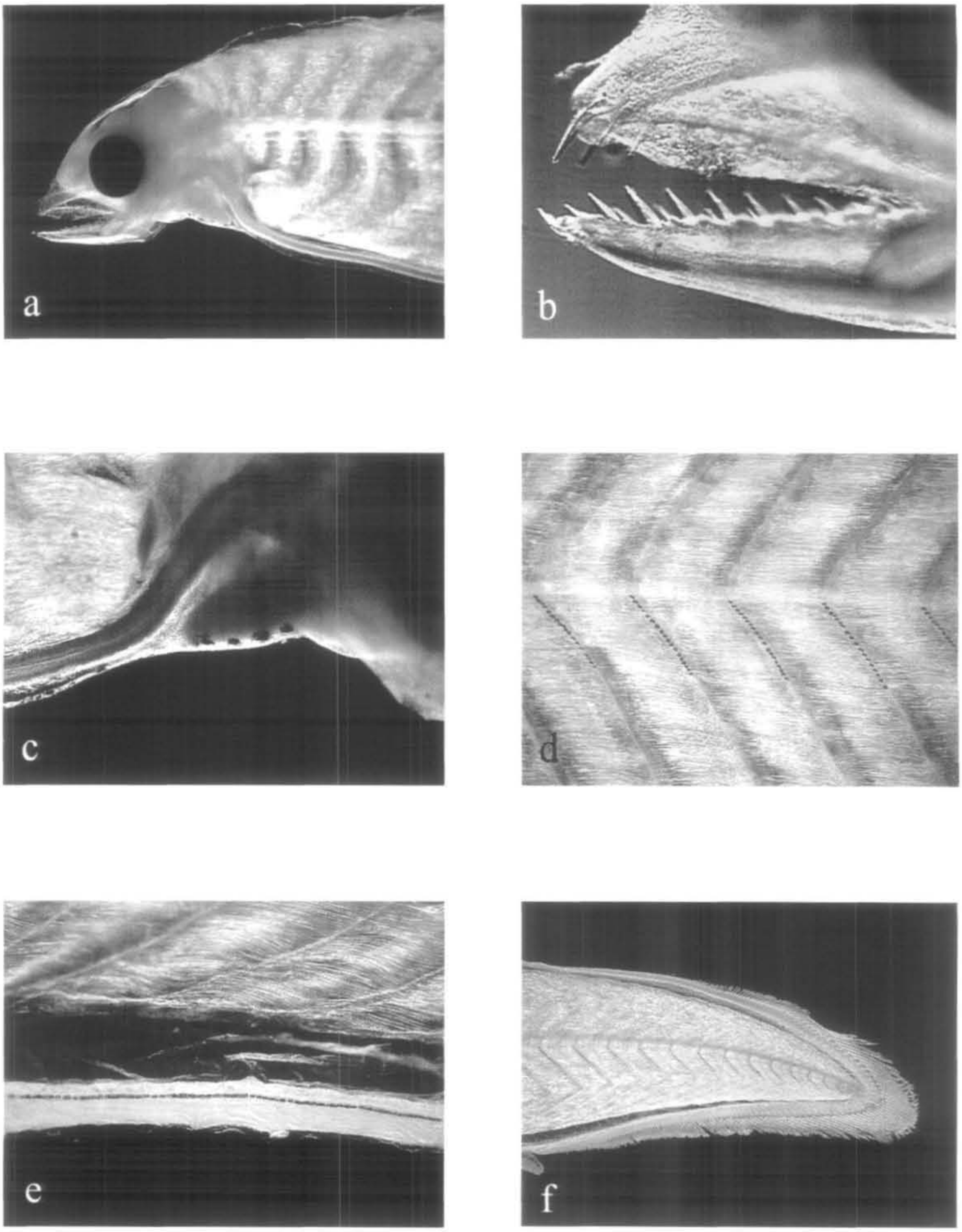


PLATE 2. Congridae-*Congrellus anago*(non Temm. and Schleg.)
a. Head b. Teeth c. Pigmentation beneath heart
d. Lateral pigmentation e. Pigmentation on
dorsal side of intestine f. Tail

Uroconger lepturus **(Richardson)**

Specimens examined = 39; total length = 50-129mm; maximum body height (excluding vertical fins) = 8mm; length of head = 4mm; length of snout = 1.28mm; diameter of eye = 1.34mm; position of nasal pit = 0.32mm; position of first nostril = 0.35mm; size of first nostril = 0.16mm; total myomeres = 152-220; pre anal myomeres = 167; post anal myomeres = 43; origin of dorsal fin = 55th myomere; dorsal fin rays = 140; anal fin rays = 75; caudal fin rays = 4+3; teeth = I+I+7+14 / I+15.

Body elongate, transparent and moderately high, tapering posteriorly to a long, pointed tail; head very short and triangular (Plate3. a); nasal organ well developed with only the anterior nostril discernible (in the specimen examined); eye prominent and slightly oval; cleft of mouth oblique and extends to the middle of the eye; upper jaw marginally longer than the lower jaw; both jaws provided with pointed, forwardly directed teeth (Plate3. c)- each half of the upper jaw with single, antero-dorsally placed, short, grasping tooth followed by a very long , slightly curved, acute tooth; rest of the teeth arranged in two groups: first group composed of seven moderately long, pointed teeth and the second group have 14 small, closely arranged teeth in the posterior half of upper jaw; lower jaw possesses on its each half a slightly curved, pointed grasping tooth placed just below its tip followed by 14 fairly long teeth decreasing in height posteriorly; branchiostegal rays discernible (approx.11), curving towards the opercular region; pectoral fin large, circular to oval with indistinct rays (Plate3. d); dorsal fin long, well developed with distinct rays, origin of dorsal fin (55th myomere) very much ahead of the anal fin origin; anal fin short in comparison with dorsal fin but with discernible rays, though less developed than the dorsal fin rays; posterior most rays of both dorsal and anal fins longer in comparison with the anterior ones; caudal fin with 7 very long, clearly distinct rays (Plate3. g); hypurals well developed; alimentary canal long, straight and opens below 167th myomere.

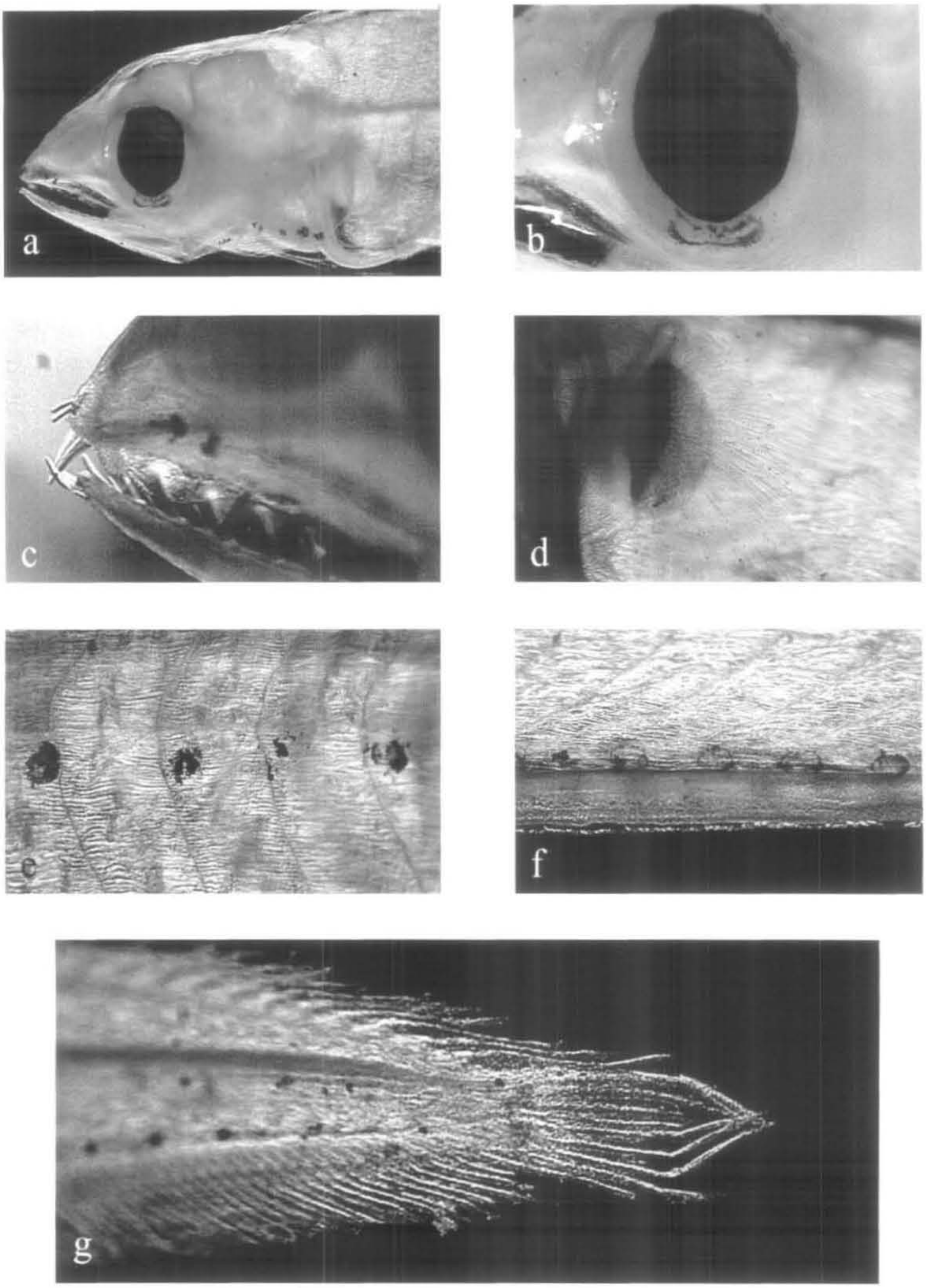


PLATE 3. Congridae-*Uroconger lepturus* (Richardson)
a. Head b. Pigmentation below eye c. Teeth
d. Pectoral fin e. Lateral pigmentation
f. ventral pigmentation g. Tail

Pigmentation in the larva is very conspicuous: two distinct pigment spots on the anterior margin of the upper jaw; group of chromatophores below the eye (crescent shaped) (Plate3. b); curved pigment patch above the eye; near the heart 6-7 black pigments cells are present – apart from the above described pigmentation rest of the head is devoid of any pigments; pigmentation on the body of the larva as follows: a mid lateral row of large, round, unbranched, black chromatophores – starting from 12^{th} myomere onwards (Plate3. e), occurring regularly on all myomeres with occasional absence on some, become discontinuous towards tail; a similar row of chromatophores present ventrally on the dorsal side of the alimentary canal (Plate3. f), continuing to the post anal region, just above the base of anal fin where it becomes slightly scattered; all the fin rays without any pigmentation.

Type A

Specimens examined = 27; total length =30-188mm; maximum height (excluding vertical fins) = 7mm; length of head = 3mm; length of snout = 0.99mm; diameter of eye = 0.74mm; position of nasal pit = 0.52mm; size of first nostril = 0.13mm; position of first nostril = 0.55mm; total myomeres =115-128; pre anal myomeres = 111; post anal myomeres = 9; teeth = I+I+3+6 / I+3+6.

Body elongate, gradually tapering towards tail than head; head small (Plate4. a); snout conical, moderately pointed; cleft oblique, slightly curved, reaching to the middle of eye; nasal organ developed with only the anterior nostril discernible; eye circular and prominent; each half of the upper jaw with a slender, antero-dorsal tooth (Plate4. b), a pointed, slightly curved large tooth followed by three moderately large teeth and group of six large teeth in the posterior part; lower on its each half is provided with an upwardly curved, sharp tooth originating from just below the tip followed by three large teeth and six comparatively large teeth; pectoral fin small with poorly developed rays; dorsal and anal fins restricted to the posterior; caudal fin poorly developed; fin rays on dorsal, anal and caudal fin not distinct (Plate4. d); hypurals distinct; intestine long, straight with out any loops.

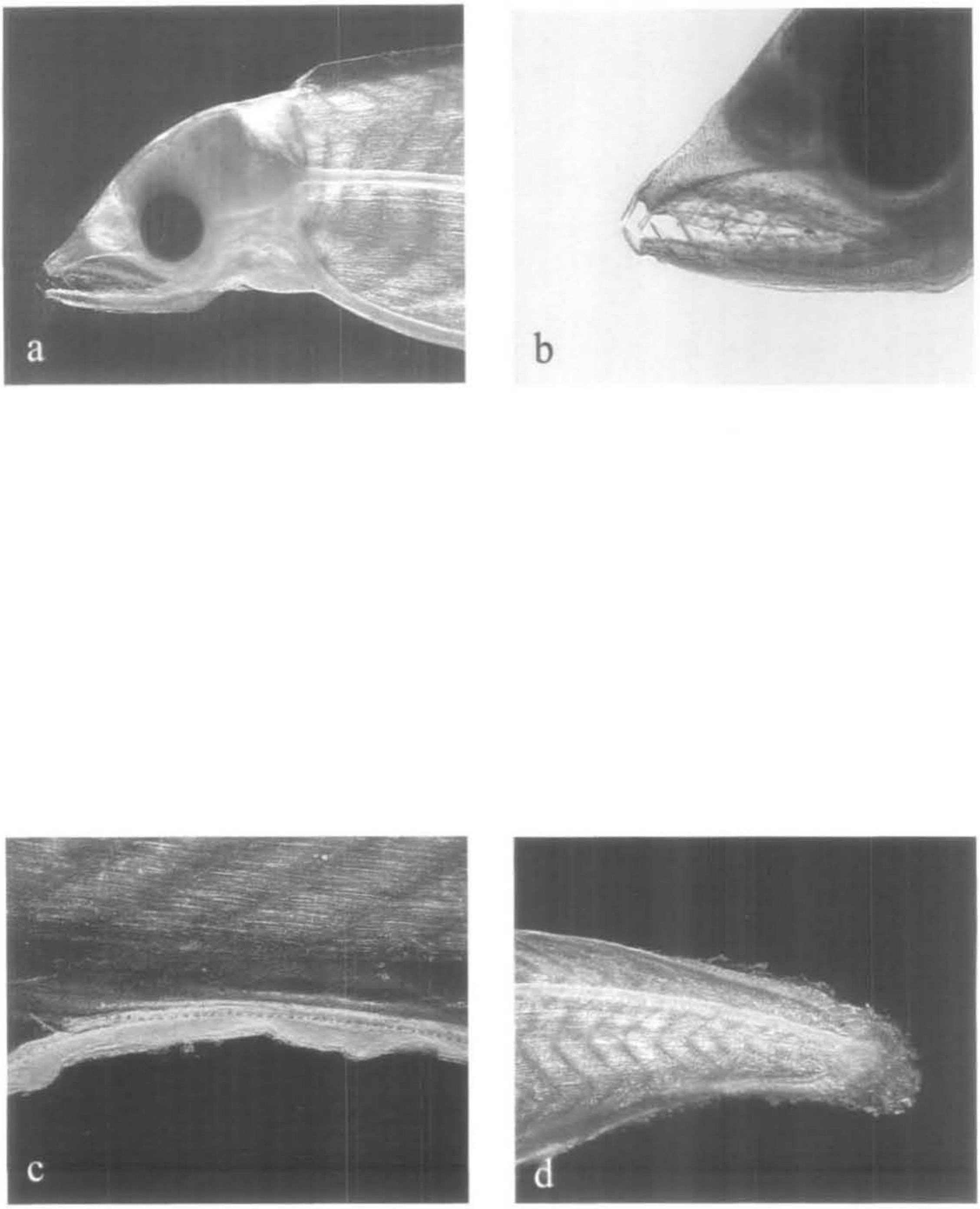


PLATE 4. Congridae-Type A
a. Head b. Teeth c. Pigmentation on dorsal side of intestine d. Tail

A mid dorsal row of stellate chromatophores, starting from the level of 5^{th} myomere and reaching up to the origin of dorsal fin; a row of pigment spots outlining the myosepta just below the mid lateral line forming a series of short diagonal lines from head to tail; a ventral row of chromatophores on the gut anterior to the gastric region, posterior to which it shifts to the dorsal side of the intestine (Plate4. c); majority of the dorsal, anal and caudal fin rays with pigmentation on its base; head, heart and pectoral fins with out any predictable pigmentation.

Type B

Specimens examined = 2; total length = 56-58mm; maximum height (excluding vertical fins) = 6mm; length of head = 3mm; length of snout = 1.25mm; diameter of eye = 0.74mm; position of nasal pit = 0.8mm; total myomeres = 136-138; pre anal myomeres = 131; post anal myomeres = 7; origin of dorsal fin = 126^{th} myomere; teeth = I+3+6 / I+3+6.

Body long with a moderately pointed tail; head small (Plate5. a) with a bluntly pointed snout; cleft of mouth slightly oblique, reaching to the middle of the eye; both jaws of the same length; eye sub circular; nasal organ well developed with out discernible nostrils; a prominent constriction near the nasal organ; dentition on each half of the jaw as follows: upper jaw with a slender, antero-dorsal tooth followed by three large teeth and six small teeth; single upwardly curved tooth originating just below the tip, three comparatively large teeth increasing in length posteriorly, six small teeth are present on the lower jaw; pectoral fin slightly oval with indistinct rays; dorsal and anal fins restricted to the posterior, with feeble rays; hypurals well developed (Plate5. e) though caudal fin very feeble; intestine long, straight with out loops or swellings reaching more than $3/4^{th}$ the length of body, opening below 131^{st} myomere.

A row of closely packed pigment spots above the eye (Plate5. b); a few scattered chromatophores on the dorsal side; row of pigment spots outlining the myosepta immediately below the midline forming a series of oblique lines from the

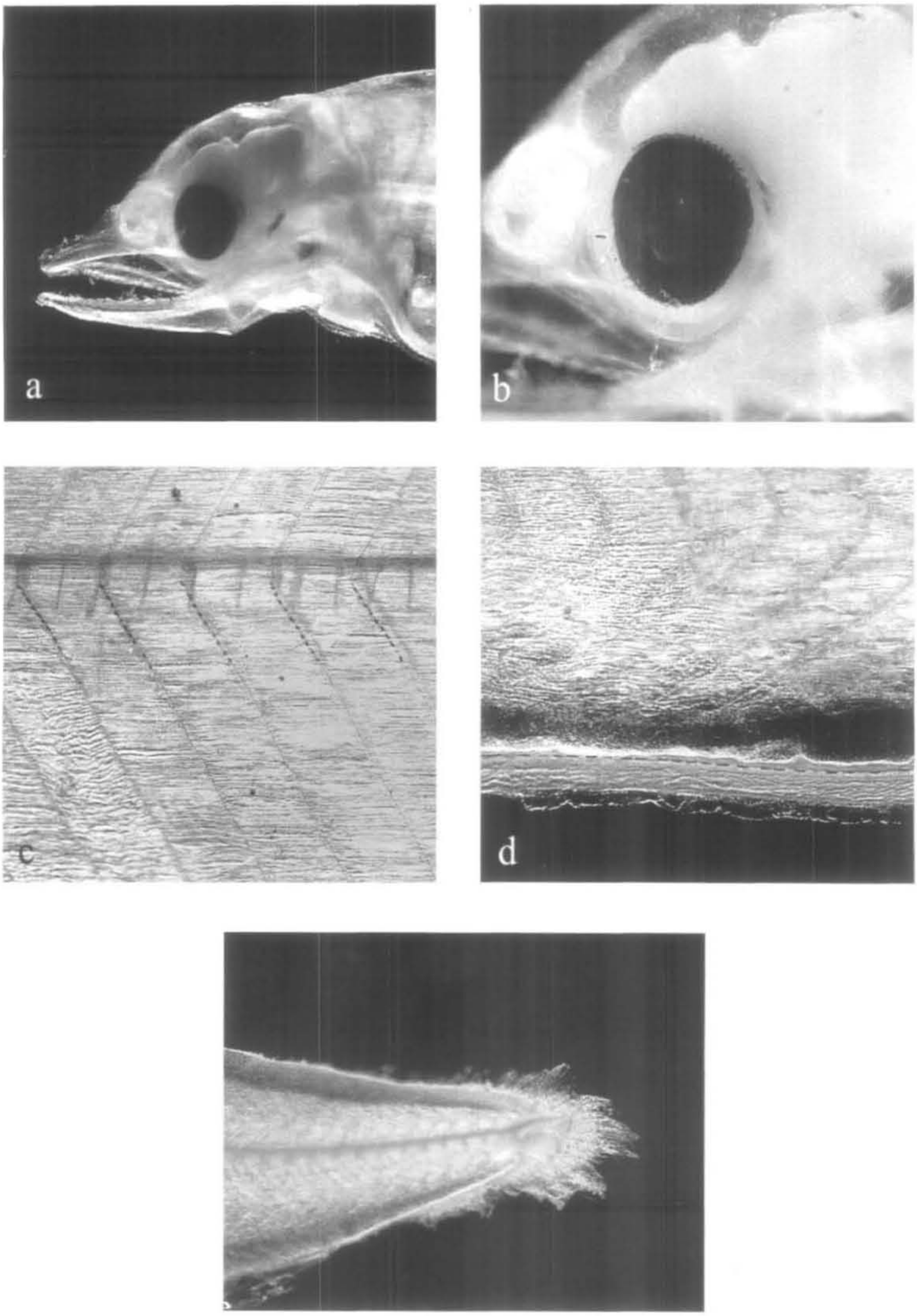


PLATE 5. Congridae-Type B

a. Head b. Pigmentation on eye c. Lateral pigmentation d. Pigmentation on dorsal side of intestine e. Tail

12^{th} myosepta onwards (Plate5. c); a row of closely arranged ventral melanophores below the gut anterior to the gastric region posterior to which it shifts to the dorsal side of the intestine (Plate5. d); posterior most anal fin rays with pigmentation at its base; caudal fin, dorsal fin and pectoral fin with out pigmentation.

Family - Ophichthidae

Ophichthid larvae can be recognized by the arches or swellings in the gut, but a few forms are known in which these intestinal modifications are inconspicuous. The looped or swollen intestine is a larval character, which does not carry over into the juvenile ophichthid.

Ophichthid leptocephali have a moderately elongate and shallow body, acute snout. Tail moderate to blunt with caudal fin reduced or sometimes absent with the tail pointing out. Pectoral fin usually small, rounded or sometimes minute. Gut formed about one- half to two- thirds of standard length, with a variety of thickenings and/or arches or looped (festooned), ranging from three to sixteen equally spaced points, sometimes accompanied by the swellings of the pronephric ducts and are pigmented. Liver lobed sometimes with two or three connected or separate lobes.

Pigmentation often conspicuous, consisting of patches of minute chromatophores, occurring occasionally on the head, jaws etc. Lateral pigmentation variable – present along the midline in the form of a row of pigment patches – cutaneous or subcutaneous, pre anal or post anal and some times a combination of all or may be present in the form of a outlining of minute melanophores on the myosepta forming a series of diagonal lines just below the midline or as streaks of pigment on myosepta. Ventral pigmentation tends to be concentrated on the intestine mostly on the intestinal thickenings and arches. Pigmentation also on the bases of the anal and dorsal fins. Myomeres ranges from 120 to 270; total length range from 50 mm – 180 mm.

Ophichthus sp.

Specimens examined = 2; total length = 61-104mm; maximum body height (excluding vertical fins) = 5mm; length of head = 5mm; length of snout = 1.41mm; diameter of eye = 0.8mm; position of nasal pit = 0.74mm; total myomeres = 154-158; pre anal myomeres = 65; post anal myomeres = 93mm; origin of dorsal fin = 30th myomeres; dorsal fin rays = 62; anal fin rays = 218; teeth = I+6+6 / I+7+3.

Body elongate, compressed, tapering after the mid point of the post anal region; head slightly elongate to blunt (Plate6. a); snout less conical to round; nasal organ well developed, nostrils not differentiated; eye circular; cleft of mouth oblique, slightly curved, extending to the middle of the outer margin of eye; teeth sharp (Plate6. b), in three groups on each side of the upper jaw and in three groups on each side of the lower jaw as follows: in the upper jaw a fang like tooth followed by six large teeth and six smaller teeth; approximately 26 branchiostegal rays observed, continuing over the opercular region; pectoral fin more or less rounded with feeble rays; dorsal fin with only the posterior most rays discernible; anal fin with distinct rays; caudal fin absent, tail ending in a bluntly pointed tip (Plate6. g); intestine slightly shorter than half the total length, looped or festooned (Plate6. e) with 8 humps between adjacent loops; liver with two connected lobes (Plate6. f).

Pigmentation pattern as follows: a series of pigment spots along the margin of the upper jaw; group of pigments between the outer and inner margin of eye (Plate6. c); group of closely packed stellate chromatophores on the base of pectoral fin; lateral pigmentation as follows: single row of closely packed, stellate, branched chromatophores outlining the myosepta just below the midline, starting from myosepta 8 with irregular distribution; ten widely placed pigment patches below the midline in the post anal region (Plate6. d); cluster of pigments near the caudal region; closely packed, stellate, branched chromatophores on the dorsal side of all the eight humps of the looped intestine, a few on the base of posterior most dorsal fin rays; and on the base of all anal fin rays.

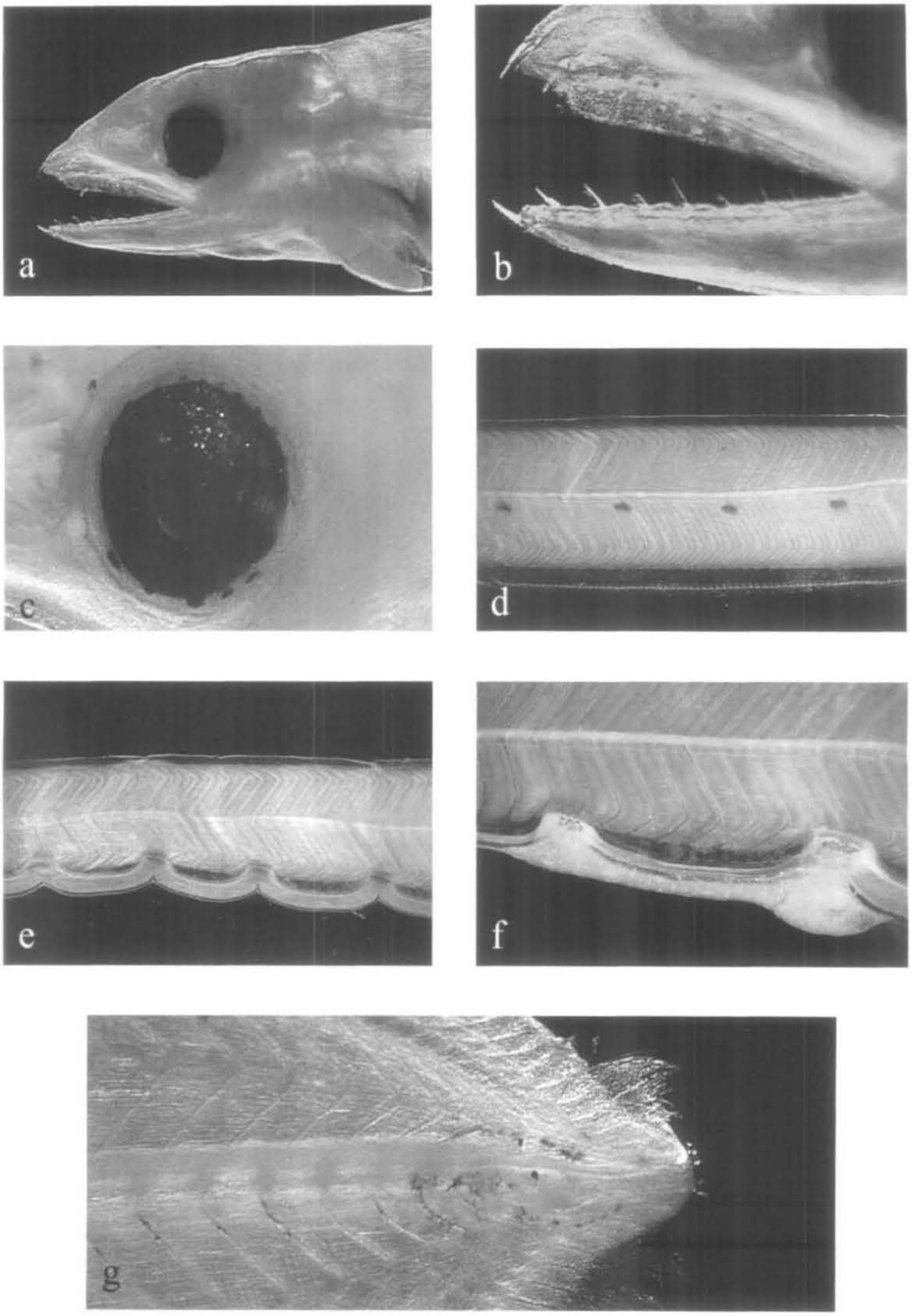


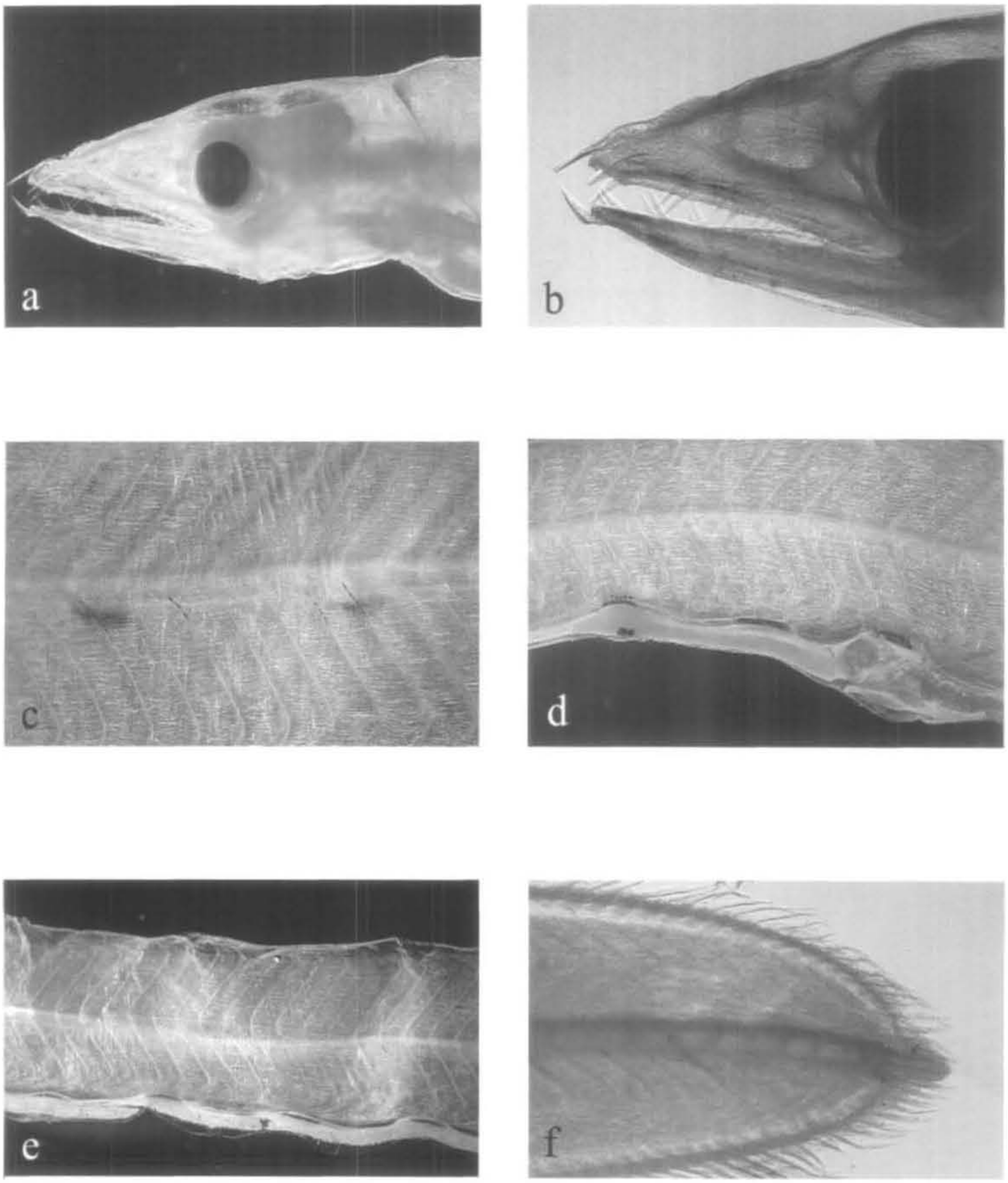
PLATE 6. Ophichthidae-*Ophichthus* sp.
a. Head b. Teeth c. Pigmentation on eye
d. Lataeral pigmentation (post anal) e. Intestine
f. Liver g. Tail

Ophisurus sp.

Specimens examined = 2; total length = 105-113mm; maximum body height (excluding vertical fins) = 2mm; length of head = 4mm; length of snout = 1.28mm; diameter of eye = 0.61mm; position of nasal pit = 0.64mm; total myomeres = 220-223; pre anal myomeres = 79; post anal myomeres = 141; origin of dorsal fin = 22^{nd} myomeres; dorsal fin rays = 57; anal fin rays = 342; teeth I+ I+ 5+5 / I+6+5.

Body long, compressed and shallow; tapering towards the posterior after the midpoint; head elongate (Plate7. a) and well differentiated from the trunk; snout sharply conical; nasal organ well developed, with two nostrils not yet separated; eye sub circular; cleft of the mouth oblique, straight extending to below the outer margin of the eye; teeth relatively acute (Plate7. b), in four groups on each side of the upper jaw and in three groups on each half of the lower jaw as follows: in the upper jaw a relatively slender clasper like antero- dorsal tooth, a single fang like tooth followed by a series of six large teeth and five smaller teeth; branchiostegal rays not clear; pectoral fin short with indistinct rays; dorsal fin well developed originating from myomeres 22, except for the posterior most rays the anterior ones are not discernible, ending sub terminally; anal fin also well developed with conspicuous rays; caudal fin absent and the tail protrudes out as free pointed tip (Plate7. f); liver with two connected lobes (Plate7. d); intestine less than half the total length with 17 prominent swellings (Plate7. e).

Pigmentation occurring invariably along various positions on the body, in detail, as follows: two streaks of chromatophores on the middle of the margin of upper jaw; two pigment spots near the tip of lower jaw; a vague pigment patch on the base of pectoral fin; streaks of pigment on the myosepta just below the midline, starting from the 22^{nd} myomeres, with no regularity in its occurrence; post anal region with 29 internal pigment patches just below the midline (Plate7. c); closely packed stellate chromatophores on the dorsal side of the 17 prominent swellings of the gut; dorsal fin devoid of any pigments on the bases of its rays; majority of the bases of anal fin rays have pigmentation; cluster of pigments near the caudal region.



PALTE 7. Ophichthidae-*Ophisurus* sp.
a. Head b. Teeth c. Lateral pigmentation
(post anal) d. Liver e. Intestine f. Tail

Phaenomonas sp.

Specimens examined = 1; total length = 93mm; maximum body height (excluding vertical fins) = 6mm; length of head = 5mm; length of snout = 1.8mm; diameter of eye = 0.8mm; position of nasal pit = 1.02mm; total myomeres = 273; pre anal myomeres = 87; post anal myomeres = 186; origin of dorsal fin = 48^{th} myomere; dorsal fin rays = 20; anal fin rays = 324; teeth = I+(5+3)+7 / I+8+3.

Body elongate, tapering posteriorly to a pointed tail; head moderately elongate (Plate8. a); snout conical; nasal region well developed without distinctive anterior and posterior nostrils; eye circular; cleft of mouth straight, extending behind the centre of the eye; teeth in three groups on each half of the upper jaw and in three groups on each half of the lower jaw as follows (Plate8. b): a fang like forwardly directed tooth in the front followed by eight larger teeth (of which the posterior three are comparatively smaller than the anterior five) and seven much smaller teeth; lower jaw with single forwardly directed tooth followed by eight larger teeth and three smaller teeth; branchiostegal rays present (more than 11); pectoral fin round; dorsal fin with only the posterior most rays distinct; anal fin with fully developed rays; caudal fin present with four distinct rays (Plate8. f); liver with three separate lobes (Plate8. e); intestine heavily looped or festooned (Plate8. d), with eight swellings or humps at the angle between adjacent loops.

Pigmentation on the larva is as follows: row of pigment spots on the posterior margin of the upper jaw; cluster of pigments near the tip of lower jaw; a few pigment spots behind the eye on the hind brain; group of internal pigment spots anterior to heart; pigment spots near the base of pectoral fin; lateral pigmentation in the form of closely packed, stellate, branched chromatophores outlining the myosepta with no regularity; ten widely placed internal pigment patches below the mid lateral line in the post anal region (Plate8. c); large cluster of pigments near the caudal region; closely packed, stellate, branched chromatophores on the dorsal side of eight thickenings of the highly looped intestine; pigments on the bases of a fewer dorsal fin rays; most of the anal fin rays with pigments at its base.

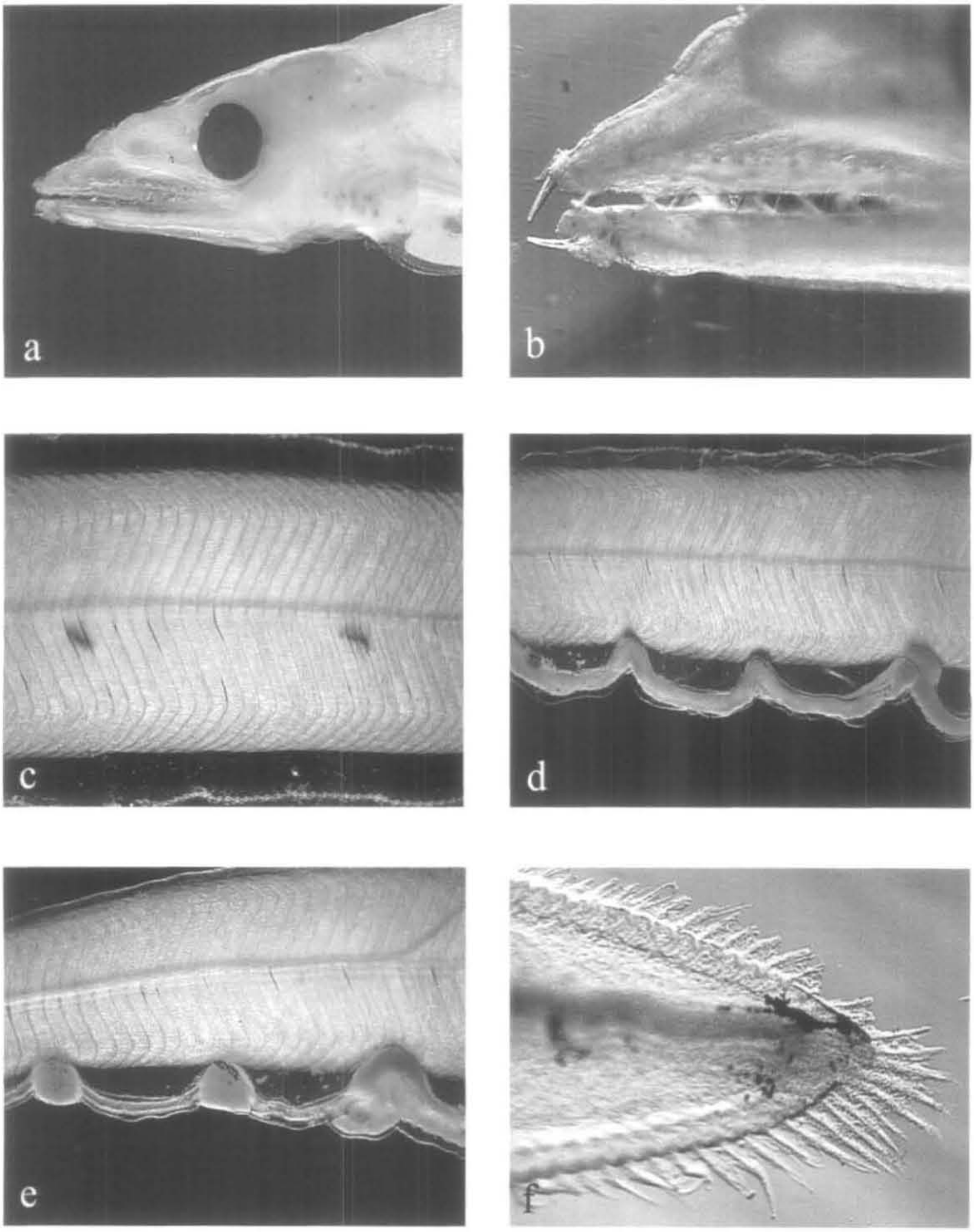


PLATE 8. Ophichthidae- *Phaenomonas* sp.
a. Head b. Teeth c. Lateral pigmentation (post anal) d. Intestine e. Liver f. Tail

Type A

Specimens examined = 4; total length = 77-89mm; maximum body height (excluding vertical fins) = 7mm; length of head = 5mm; length of snout = 1.34mm; diameter of eye = 0.8mm; position of nasal pit = 0.45mm; total myomeres = 129-131; pre anal myomeres = 66; post anal myomeres = 65; origin of dorsal fin = 60^{th} myomere; dorsal fin rays = 137; anal fin rays = 162; teeth = I+I+6+6 / I+9

Body compressed, elongate with more or less uniform height; posterior part tapering to a rather bluntly pointed tail; snout bluntly pointed (Plate9. a); upper jaw slightly longer than the lower jaw; nostrils not distinct; cleft straight, extending behind the middle of the eye; eye slightly oval; well developed sharp teeth on both jaws as follows: in upper jaw four groups of teeth – an antero-dorsal tooth, a fang like tooth, followed by six large teeth and six comparatively smaller teeth; in lower jaw two sets of teeth – a fang like teeth in the front followed by nine teeth which gradually decrease in size posteriorly; branchiostegal rays distinct (more than 21) continuing upwards over the opercular region; pectoral fin well developed though with indistinct rays; dorsal and anal fins well developed with distinct rays; caudal fin absent and the tail protrudes out as a free pointed tip (Plate9. d); hypurals well developed; liver with two connected lobes (Plate9. c); intestine slightly more than ½ the total length, looped (Plate9. b) with nine humps or thickenings between each loop.

Pigmentation was very prominent in the larva and is described as follows: two pigment spots on the anterior margin of the upper jaw; closely packed, branching chromatophores near the base of pectoral fin; six internal pigment patches in the post anal region below the midline; minute widely placed pigment spots numbering 1to5 outlining the myosepta just below the midline starting from the 11^{th} myosepta onwards; where the internal patches are present, they appear as closely packed and branched, giving the appearance of streaks or lines on the myosepta; a small cluster of pigments near the caudal tip; pigmentation above the nine thickenings on the intestine as follows: chromatophores on the first thickening are closely packed and form a

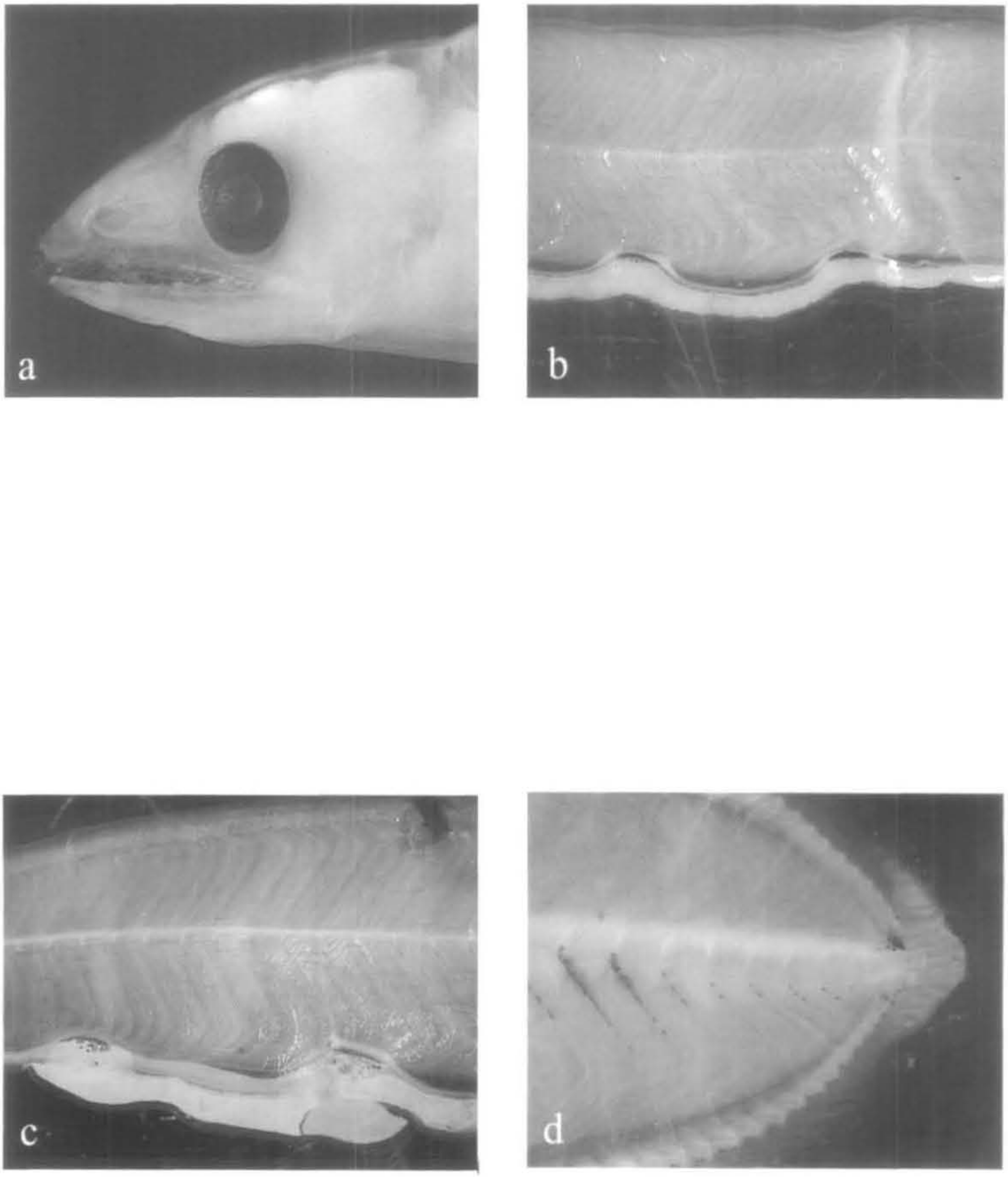


PLATE 9. Ophichthidae-Type A
a. Head b. Intestine c. Liver d. Tail

hexagonal, honey comb like pattern; chromatophores above the rest of the thickenings are stellate, branched and closely packed; dorsal fin rays devoid of any pigments on its base; all anal fin rays with pigmentation on its base.

Type B

Specimens examined = 1; total length = 46mm; maximum height (excluding the vertical fins) = 4mm; length of snout = 1.28mm; diameter of eye = 0.67mm; position of nasal pit = 0.77mm; total myomeres = 149mm; pre anal myomeres = 81mm; post anal myomeres = 68mm; origin of dorsal fin = 56^{th} myomere; teeth = I+I+4+5 / I+6+3.

Body elongate, tapering gradually towards the posterior after the midpoint ending in a bluntly pointed tail; head elongate (Plate10. a) and well differentiated from trunk; snout conical; lower jaw slightly longer than the upper jaw; nasal organ well developed with the nostrils not yet separated; cleft of mouth slightly oblique, curved, reaching beyond the middle of the eye; eye oval; each half of both the jaws with acute teeth as follows (Plate10. b): upper jaw with four groups of teeth ¬ a large antero-dorsal tooth followed by a fang like tooth, four large teeth and five smaller teeth; lower jaw with a single, large almost horizontally placed tooth in the tip, six large teeth followed by three smaller teeth; branchiostegal rays not visible; pectoral fin with feeble rays; dorsal and anal fins with indistinct rays; caudal fin absent and tail freely protrudes out (Plate10. e); hypurals well developed; intestine nearly $3/4^{th}$ length of body, highly looped (Plate10. d)with nine humps or thickenings between adjacent loops; liver with two connected lobes (Plate10. c).

Pigmentation very conspicuous in the leptocephalus and described as follows: three pigment spots on the margin of the upper jaw; a less conspicuous pigment patch on the base of the pectoral fin; five internal pigment patches in the post anal region below the mid lateral line; streaks of pigment present above the patches and on the last three myosepta; pigment clusters near the caudal region; highly branched, stellate, closely packed group of chromatophores above the nine intestinal humps or

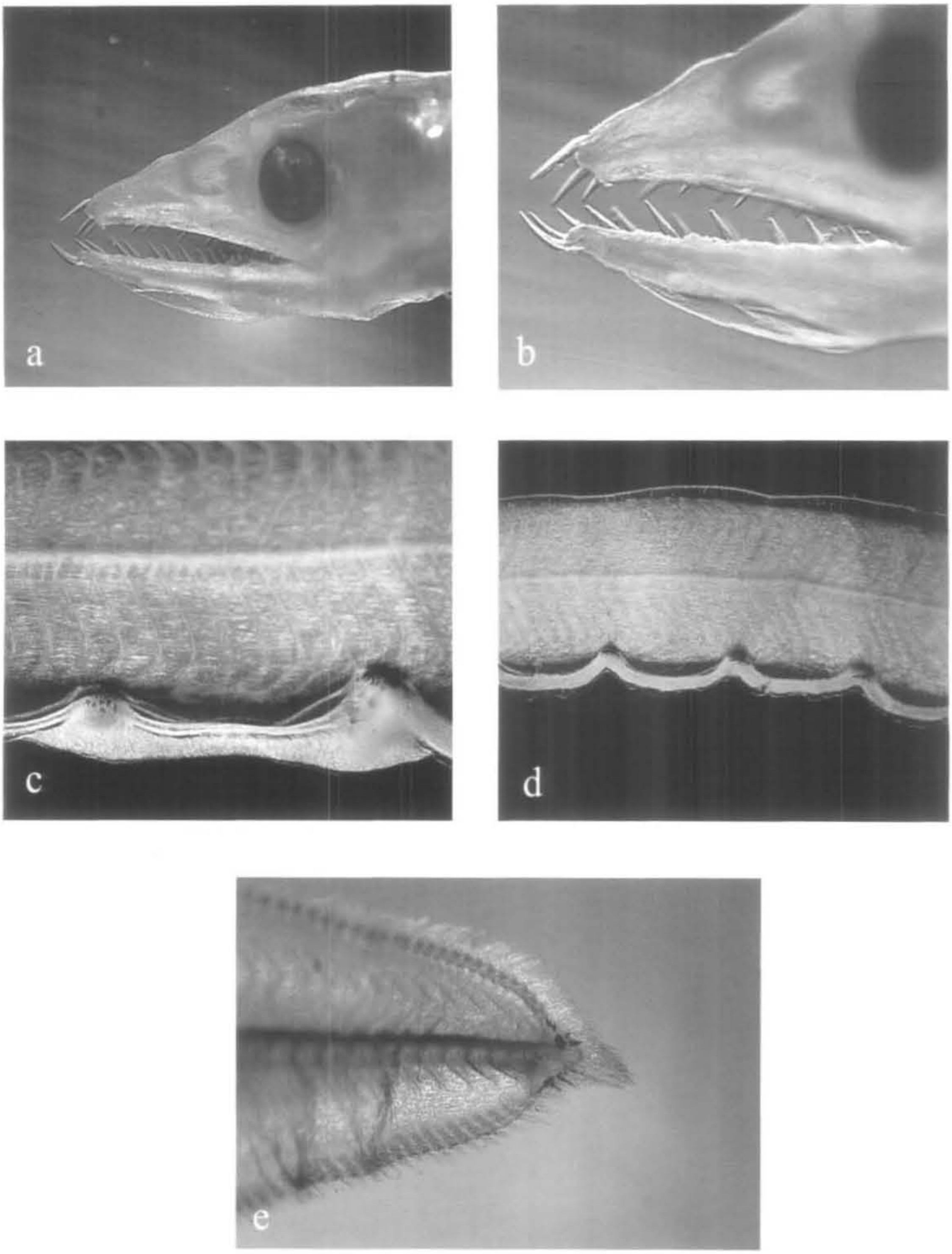


PLATE 10. Ophichthidae-Type B
a. Head b. Teeth c. Liver d. Intestine e. Tail

thickenings; dorsal and anal fins devoid of any pigments.

Type C

> Specimens examined = 2; total length = 42-48mm; maximum body height (excluding vertical fins) = 3mm; length of head = 4mm; length of snout = 1.7mm; diameter of eye = 0.58; position of nasal pit = 1.1mm; total myomeres = 146-149; pre anal myomeres = 83mm; post anal myomeres = 66; origin of dorsal fin = 79th myomere; teeth = I+I+3+6 / I+6+2.

Body more or less of uniform height, posteriorly ending in a blunt tail; head moderately elongate (Plate11. a); snout conical; upper and lower jaws of the same length; nasal region well developed with nostrils not distinct; cleft of mouth oblique, curved, reaching up to the middle of the eye; eye circular; upper and lower jaws provided with sharp teeth on its each half (Plate11. b): in the upper jaw a single, large antero-dorsal tooth followed by a large tooth three comparatively smaller teeth than the preceding ones and in the posterior are six very small teeth; in the lower jaw a single large tooth in the tip followed by six large teeth and two small teeth; branchiostegals not clear; pectoral fin long with indistinct rays; dorsal and anal fin ends abruptly near the caudal fin, with very feeble rays; caudal fin absent; hypurals well developed and freely protrudes out (Plate11. f); intestine more than ½ the total length, looped or festooned with nine prominent humps or thickenings at the junction between adjacent loops and eight less prominent thickenings in the middle of each loop; liver with two connected lobes (Plate11. e).

The larva is very conspicuously pigmented with a very vague pigment patch on the tip of upper jaw; single pigment spot on the middle of the margin of upper jaw; patch of pigment on the tip of lower jaw; another pigment patch near the hind brain; cluster of pigment spots near the base of pectoral fin; dorsal and anal fin ray bases with out any pigmentation; cluster pigments near the caudal region; lateral pigmentation in the form of twenty widely placed internal pigment patches on the mid line (Plate11. c), starting from 10th myosepta onwards; streaks of pigment just

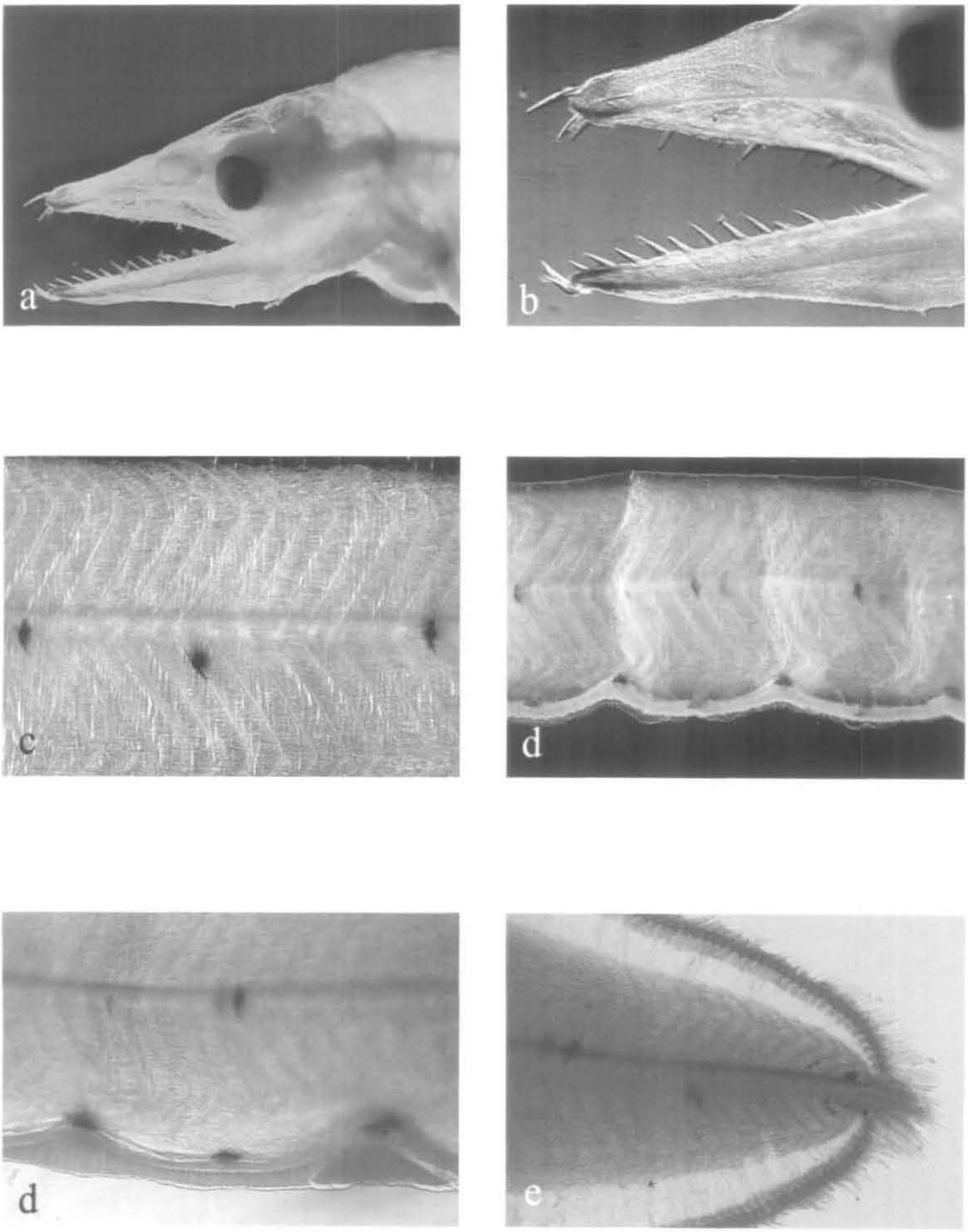


PLATE 11. Ophichthidae-Type C
a. Head b. Teeth c. Lateral pigmentation
d. Intestine e. Liver f. Tail

below the mid lateral line starting from 14^{th} myosepta; nine widely placed clusters of branching chromatophores in the post anal region just above the anal fin; branched, closely packed group of chromatophores on all the thickenings of the intestine (Plate11. d).

Type D

Specimens examined = 1; total length = 90mm; maximum body height (excluding vertical fins) = 6mm; length of head = 6mm; length of snout 2.01mm; diameter of eye = 0.8mm; position of nasal pit = 1.28mm; total myomeres = 142mm; pre anal myomeres = 76; post anal myomeres = 66; origin of dorsal fin = 72^{nd} myomere; dorsal fin rays = 210; anal fin rays = 200; teeth = I+I+4+6 / I+7+3.

Body moderately elongate, compressed, tapering posteriorly to a slightly round tail; head moderately elongate (Plate12. a); snout conical; upper jaw longer than lower jaw; nasal organ developed, with anterior nostrils not yet separated; cleft of mouth oblique, curved, reaching to the middle of the eye; eye round; well developed acute teeth on each half of both the jaws (Plate12. b): in upper jaw an antero-dorsal tooth followed by a single large fang like tooth; four large teeth and a series of six small teeth; in lower jaw a single large tooth anteriorly, followed by seven large teeth and a set of three small teeth; branchiostegals developed (more than 16); pectoral fin round with indistinct rays; dorsal and anal fins well developed with distinct rays; caudal fin present with three distinct rays (Plate12. f); hypurals present; intestine looped (Plate12. d), more than ½ the total length with nine thickenings between adjacent loops; liver with two connected lobes.

Larval pigmentation is very prominent and described as follows: three pigment spots on the margin of upper jaw; cluster of pigment spots near the base of pectoral fin; no pigmentation on anal and dorsal fin ray bases; lateral pigmentation in three groups: first group consists of nine widely placed clusters of pigment spots in the pre anal region (Plate12. e) along the mid line starting from 8^{th} myosepta; second group of six internal pigment patches just below the mid line in the post anal region

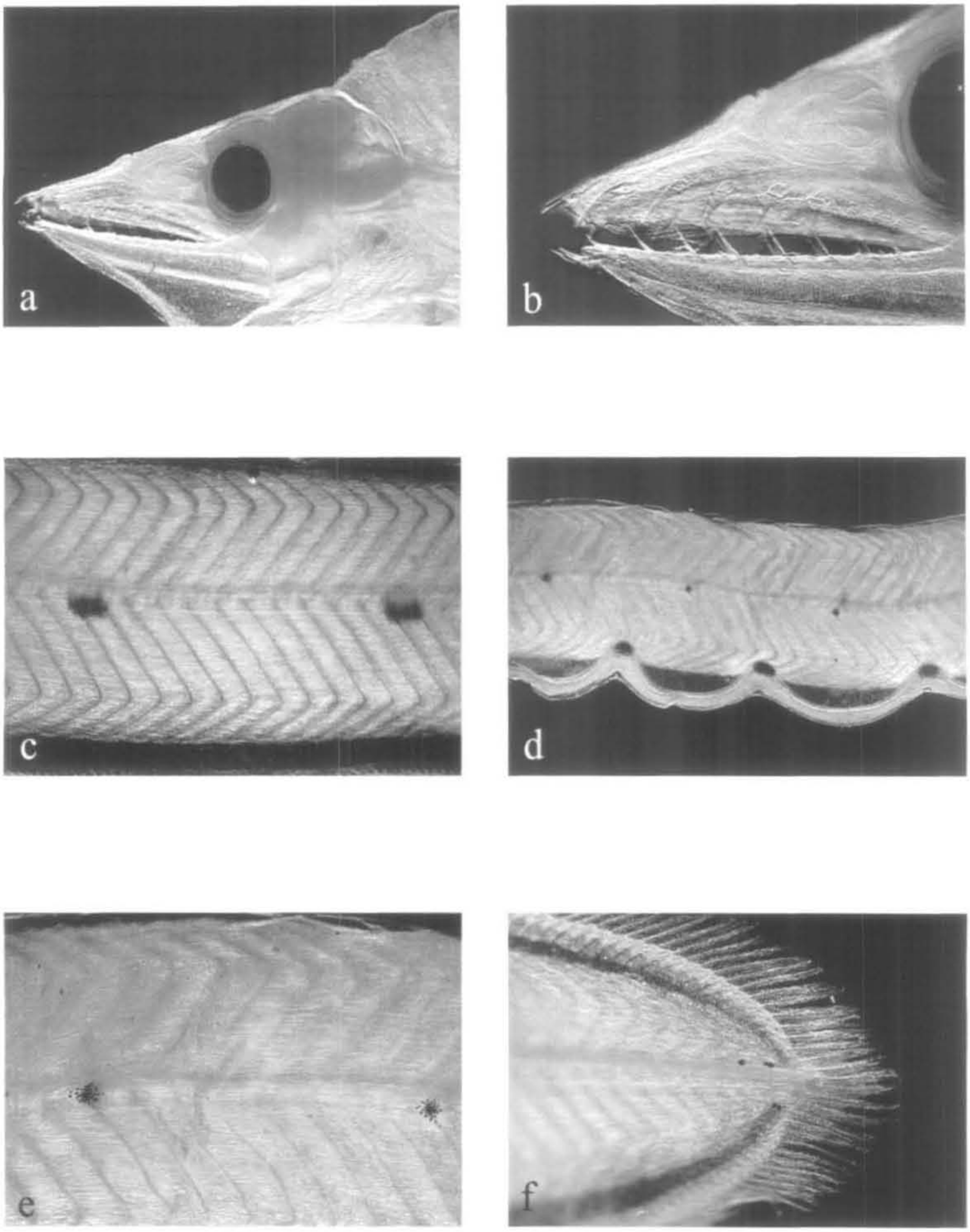


PLATE 12. Ophichthidae-Type D
a. Head b. Teeth c. Lateral pigmentation (post anal) d. Intestine e. Lateral pigmentation (pre anal) f. Tail

(Plate12. c), from the 78^{th} myomere onwards; third group consists of row of closely placed pigment spots along the myosepta just below the mid line, appearing as streaks and are mostly present in the region where the internal pigments are; five widely placed clusters of pigment spots above the anal fin; closely packed, branched chromatophores above the nine humps or thickenings of the intestine; four pigment spots near the caudal region.

Type E

Specimens examined = 19; total length = 41-62mm; maximum body height (excluding vertical fins) = 4mm; length of head = 4mm; length of snout = 1.34mm; diameter of eye = 0.74mm; position of nasal pit = 0.77mm; total myomeres =126-131; pre anal myomeres = 41; post anal myomeres = 86; origin of dorsal fin = 21^{st} myomere; dorsal fin rays = 164; anal fin rays = 209; caudal fin rays = 4+3, teeth = I+6+3 / I+7.

Body transparent, broad, leaf like, sharply tapering towards both the ends, posteriorly in a bluntly pointed tail and anteriorly in an elongate head (Plate13. a); snout sharply conical; lower jaw slightly bigger than the upper jaw; nasal pit well developed with the nostrils not distinct; cleft of mouth straight, slightly curved, reaching to the middle of the eye; eye circular; sharply pointed and forwardly directed teeth present on both jaws (Plate13. b): each half of the upper jaw is provided with a clasper like tooth in the front, followed by six large teeth and three small teeth; lower jaw on its each half have almost horizontally placed, curved tooth in the anterior most part and seven teeth gradually decreasing in size posteriorly; pectoral fin well developed and oval in shape, rays not distinct; well developed and distinct rays on both dorsal and anal fins; caudal fin with well developed hypurals and seven distinct rays (Plate13. e); intestine short, less than half the body length, not looped but with four distinct thickenings (Plate13. c); liver with two separate lobes (Plate13. d).

A row of six pigment spots on the anterior part of upper jaw; three pigment spots near the tip of the lower jaw; four branched chromatophores near the region of

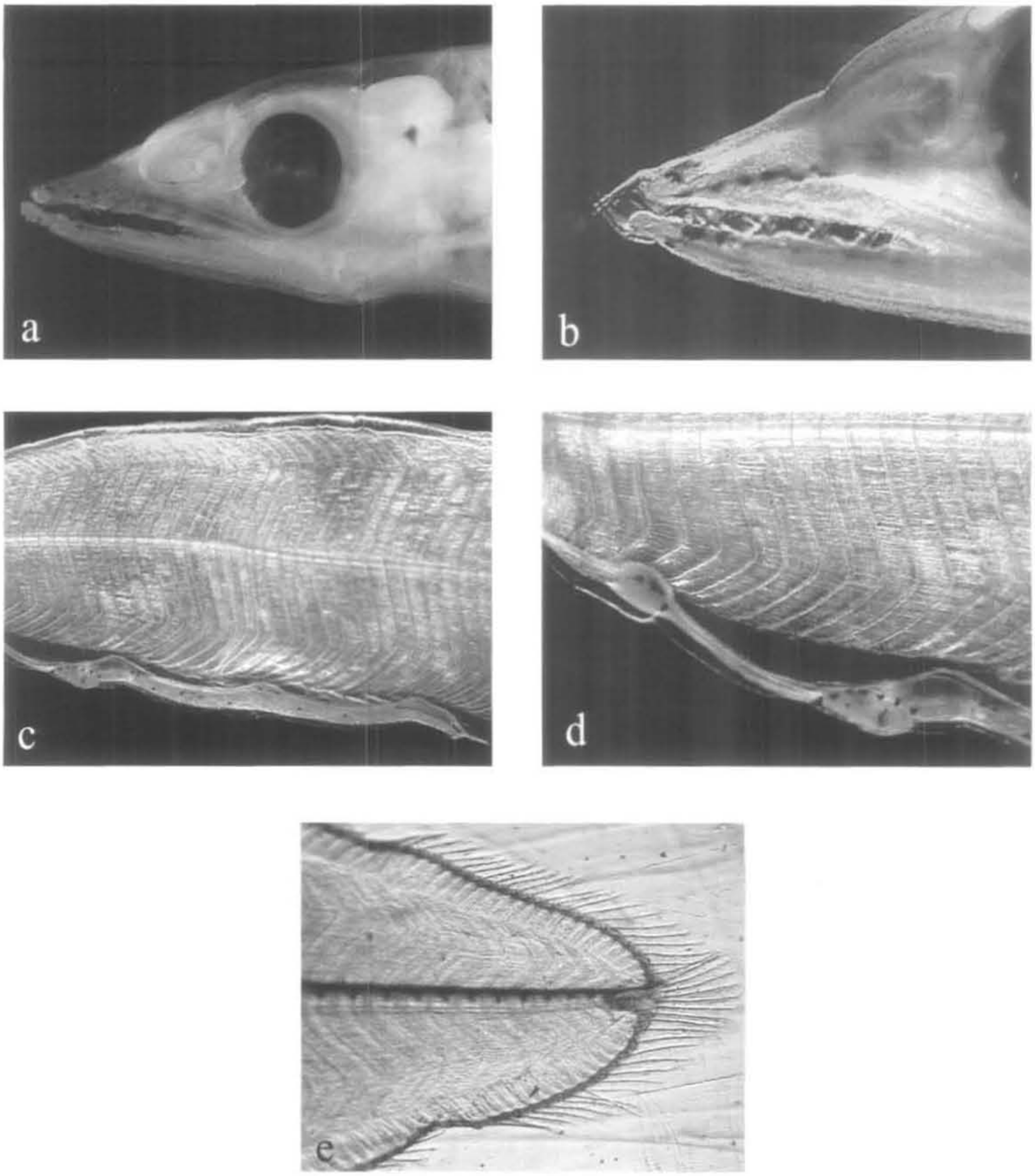


PLATE 13. Ophichthidae-Type E
a. Head b. Teeth c. Intestine d. Liver
e. Tail

hind brain; four less conspicuous, internal chromatophores ahead of the heart; two chromatophores near the base of pectoral fin; stellate, branched chromatophores present above the thickenings and also scattered on the lateral and ventral side along the length of intestine.

Except for the pigmentation described above the rest of the body of the larva was without any pigmentation.

Type F

Specimens examined = 27; total length = 38-63mm; maximum body height (excluding vertical fins) = 5mm; length of head = 4mm; length of snout = 1.22mm; diameter of eye = 0.54mm; position of nasal pit = 0.77mm; total myomeres = 123-156; pre anal myomeres = 64; post anal myomeres = 84; origin of dorsal fin = 63^{rd} myomere; dorsal fin rays = 257; anal fin rays = 184; caudal fin rays = 3+2; teeth = I+6+4 / I+6+2

Body elongate, shallow, gradually tapering posteriorly to a moderately round tail and anteriorly to a highly elongate head (Plate14. a); snout conical and pointed; lower jaw longer than upper jaw; nasal organ developed; a constriction near the nasal organ; cleft of mouth straight, slightly curved reaching to the middle of the eye; eye circular; dentition very prominent in both the jaws (Plate14. b), each half of the upper and lower jaws is provided with a clasper like, almost horizontally placed tooth in the tip; in the upper jaw six large teeth which slightly decrease in size posteriorly, are arranged behind the anterior most tooth followed by four small teeth; in addition to the anterior most tooth, lower jaw has six large teeth and two small teeth; pectoral fin oval; dorsal and anal fin well developed with distinct rays; caudal fin with five distinct rays (Plate14. d); hypurals well developed; liver with two separate lobes (Plate14. c); intestine more or less ½ the total length with three prominent thickenings, the third thickening associated with the kidney; three less conspicuous thickenings between the second and the third thickening.

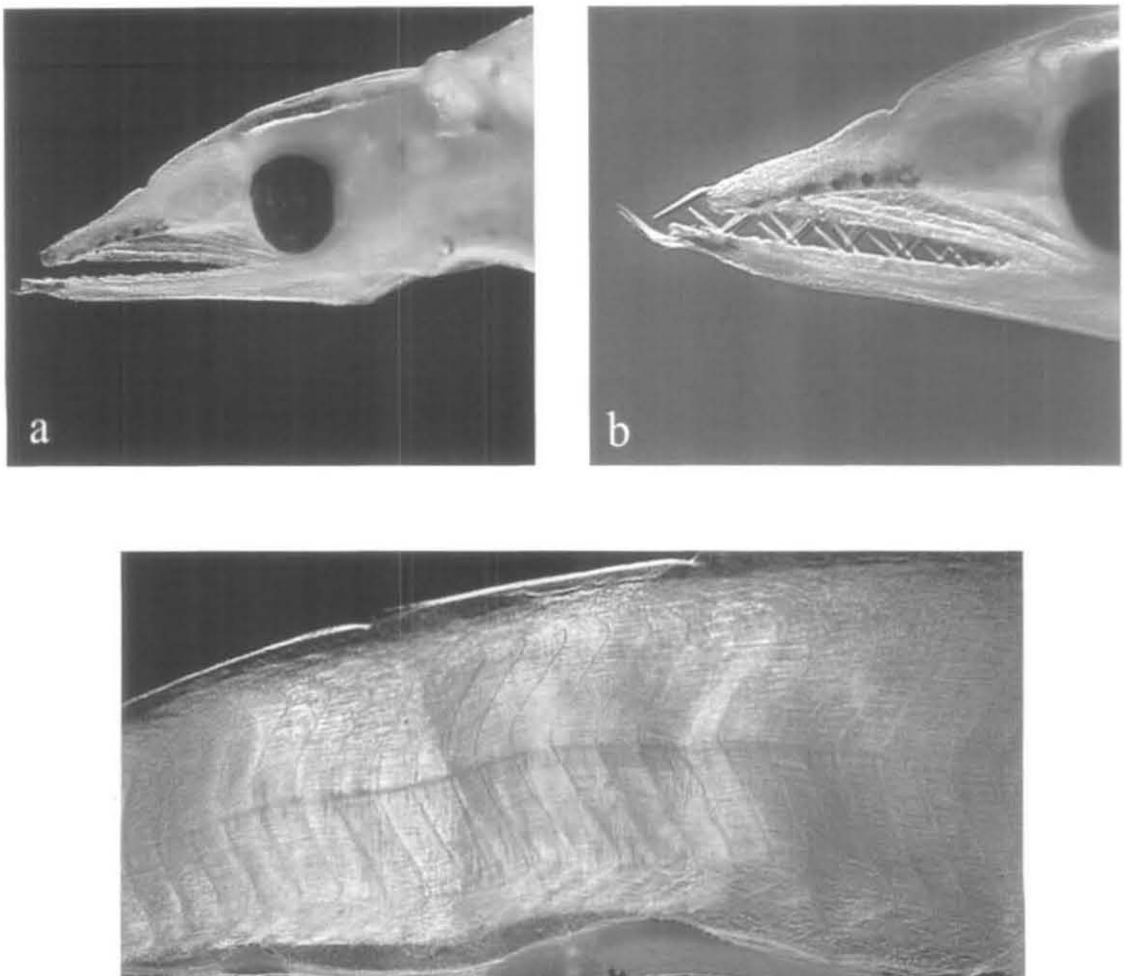


PLATE 14. Ophichthidae-Type F
a. Head b. Teeth c. Liver d. Tail

Pigmentation in the larva is conspicuous as described here: a row of chromatophores on the upper jaw extending towards the nasal organ; single patch of pigment near the tip of lower jaw; two large, stellate, branched chromatophores near the hind brain region; single pigment patch near the base of pectoral fin; a few chromatophores on the bases of posterior most dorsal fin rays; majority of the anal fin rays with pigments on its base; no lateral pigmentation; intestinal pigmentation as follows: two stellate, branched chromatophores on the ventral side of the gut anterior to the first swelling; single, branched chromatophore on the ventral side between the first and second thickenings; a few branched chromatophores below the gastric region; first thickening with branched, stellate, chromatophores on the dorsal side and in the rest of the thickenings these are between the intestine and the overlying kidney.

Family - Muraenidae

This is one of the most homogenous and one of the important of the eel families. It does not show the great variations in larval and adult morphology characteristics of the other two large eel families viz., Ophichthidae and Congridae. Muraenid larvae can be charaterised as "small to moderate sized leptocephali; body moderately deep; tail broadly rounded; gut a simple, narrow tube with out loops or thickenings, about one half to three- fourths standard length; dorsal fin variable, originating any where from shortly behind head to near tip of tail; head with short blunt snout; posterior nostril near level of upper margin of eye; pectoral fin greatly reduced, seldom more than a minute, fleshy flap but is more usually absent; pigmentation variable, may consist of small melanophores along gut, on head, dorsal midline, base of fin rays or sub cutaneously on under side of spinal cord, but never on lateral body surface; maximum size generally less than 100mm".

The greatly reduced pectoral fin is unique to muraenid larvae. Other eels have lost the pectoral fin in the adult, but only the morays shows this reduction in the larval stage. The high posterior nostril, the short, blunt snout and the broadly rounded tail further characteise the muraenid larvae.

Anarchias sp.

Specimens examined = 2; total length = 43-44mm; maximum height (excluding vertical fins) = 7mm; length of head = 3mm; length of snout = 0.9mm; diameter of eye = 0.58mm; position of nasal pit = 0.29mm; position of first nostril = 0.29mm; size of first nostril = 0.1mm; position of second nostril = 0.78mm; size of second nostril = 0.07mm; total myomeres = 103-109; pre anal myomeres = 57; post anal myomeres = 52; origin of dorsal fin = 100^{th} myomere; dorsal fin rays = 34; origin of anal fin = 103^{rd} myomere; anal fin rays = 23; caudal fin rays = 2+2; teeth = I+I+3+4 / I+5+2.

Spindle shaped, elongate body with rounded tips; head small with a convex dorsal profile (Plate15. a); snout short and round; eye sub circular; cleft of mouth oblique, straight, reaching beyond the center of eye; nostrils well developed; each half of upper jaw with a short, slender grasping tooth, a large, curved, pointed fang like tooth followed by three large teeth and four small teeth; lower jaw on its each half bears a single, curved, almost horizontally placed tooth in its tip followed by five long, slender teeth and two small teeth; pectoral fin a minute, rudimentary, fleshy flap, barely distinguishable; dorsal and anal fin restricted to the posterior, with dorsal fin originating slightly ahead of anal fin; both dorsal and anal fins with well developed rays; caudal fin supported by four rays with the hypurals difficult to distinguish (Plate15. b); anal opening at 57^{th} myomere.

The leptocephalus is devoid of pigmentation on the body, fins or intestine, which is a characteristic feature.

Gymnothorax sp.

Specimens examined = 1; total length = 58mm; maximum body height (excluding vertical fins) = 8mm; length of head = 3mm; length of snout = 0.91mm; diameter of eye = 1.34mm; position of nasal pit = 0.45mm; position of first nostril = 0.39mm; size of first nostril = 0.11mm; position of second nostril = 0.91mm; size of second nostril =

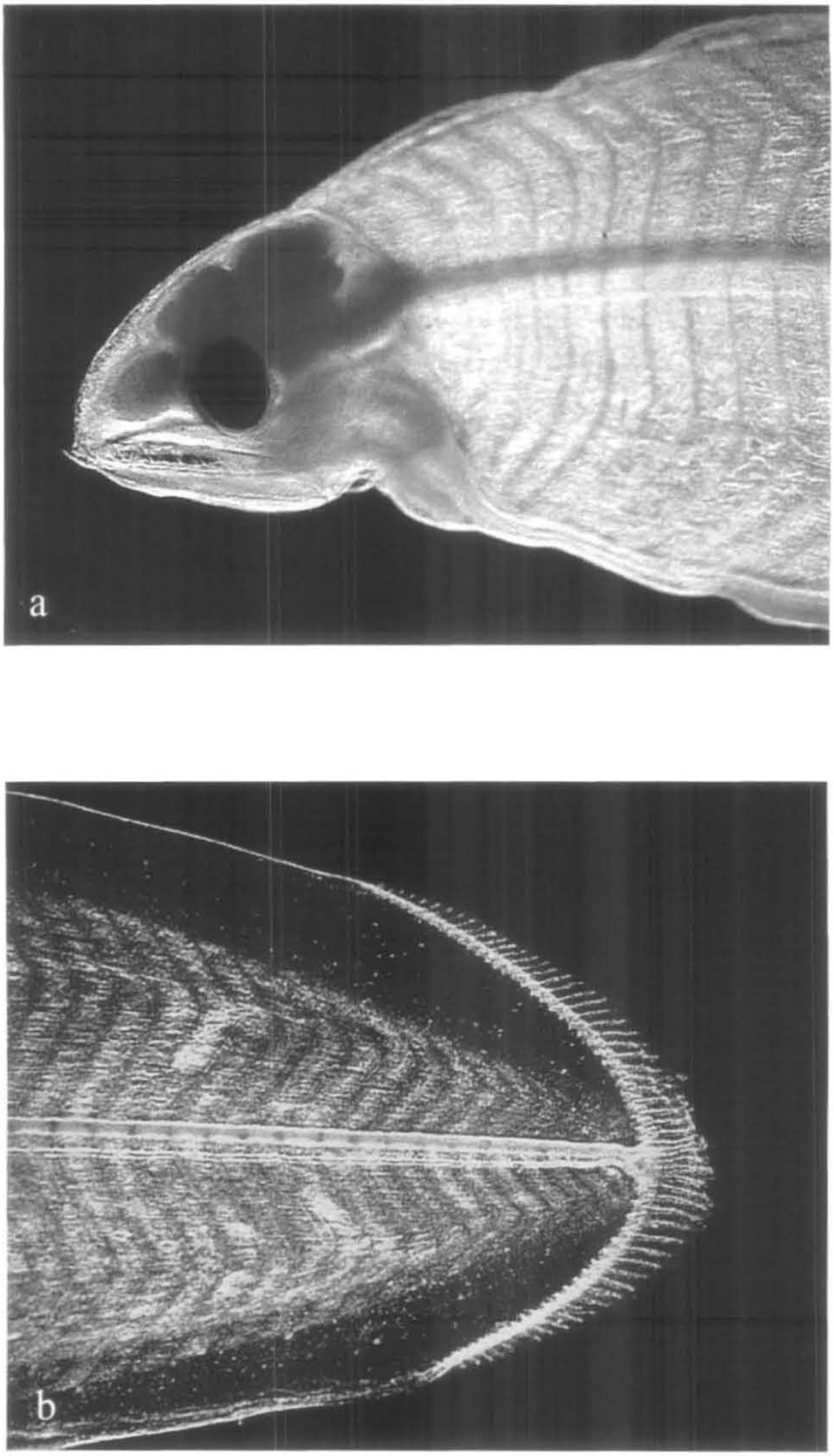


PLATE 15. Muraenidae- *Anarchias* sp.
a. Head b. Tail

0.18mm; total myomeres = 138; pre anal myomeres = 89; post anal myomeres = 49; origin of dorsal fin = 44th myomere; dorsal fin rays = 200; anal fin rays = 30; caudal fin rays = 4; teeth = I+5+5 / I+10.

Moderately elongate, spindle shaped body with broadly rounded ends; head small with a convex dorsal profile (Plate16. a); snout short, bluntly pointed; nasal organ with well differentiated nostrils, posterior nostril slightly above the upper margin of eye; eye circular; cleft of mouth slightly oblique, curved reaching beyond the centre of the eye; upper jaw marginally longer than lower jaw; teeth in the half of upper jaw consisting of three groups (Plate16. b): an anterior, slender, long, acute grasping tooth, a second series of five large teeth followed by five comparatively smaller teeth; dentition in lower jaw in two groups: an upwardly curved, sharp tooth originating from just below the tip followed by a series of ten teeth, decreasing in size posteriorly; six branchiostegal rays discernible (in the specimen examined) curving up over the opercular region; pectoral fin very small, barely distinguishable with rudiment rays; dorsal developed, originating well ahead of the anal opening with distinguishable rays; caudal fin round with four rays (Plate16. f); hypurals indistinct; anal fin with distinguishable rays; dorsal and ventral diaphanous zones becoming broader towards the posterior region; alimentary canal straight, accounting to 3/4th length of the body.

A subcutaneous row of chromatophores on the anterior margin of upper jaw; a same pattern on the ventral side of the posterior part of lower jaw; scattered minute pigment spots on the dorsal side of head, above the brain (Plate16. c); a few subcutaneous chromatophores behind the eye; 6-7 chromatophores above heart; five very small pigment spots on the base of pectoral fin; a group of stellate chromatophores ventral to the heart (Plate16. d), this continuing as a row on the ventral side of the intestine up to the anal opening; a second row of chromatophores on the dorsal side of the intestine posterior to the gastric region (Plate16. e) and continuing to the anal opening; a mid dorsal row of pigment spots originating from the 9th myomere to the origin of dorsal fin; a row of internal melanophores on the

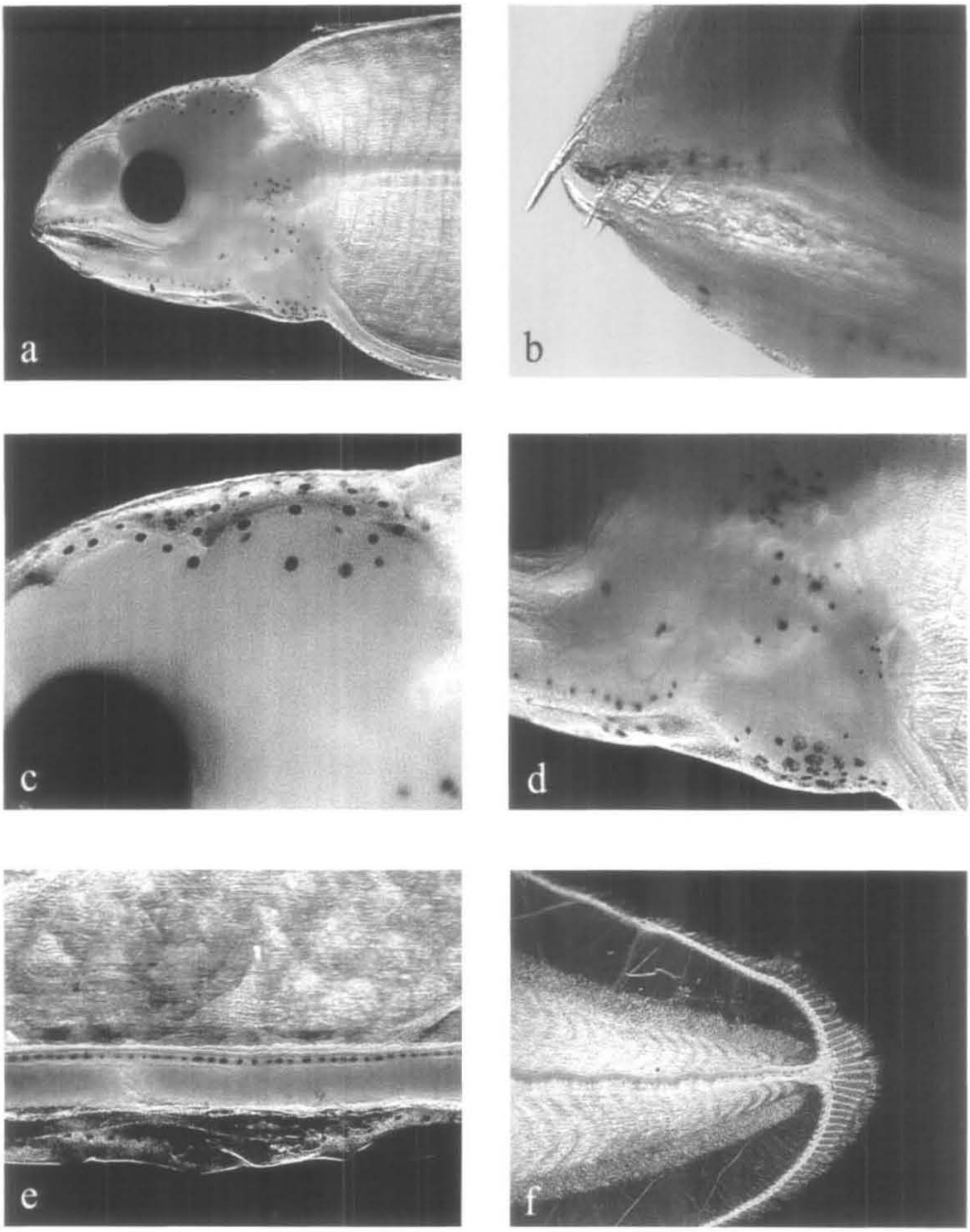


PLATE 16. Muraenidae- *Gymnothorax* sp.
a. Head b. Teeth c. Pigmentation on dorsal side of head d. Pigmentation on heart e.Pigmentation on dorsal side of intestine f. Tail

midline from head to tail; pigmentation on the base of posterior most dorsal and anal fin rays; all caudal fin rays with pigments on its base.

Uropterygius sp.

Specimens examined = 1; total length = 57mm; maximum height (excluding vertical fins) = 8mm; length of head = 3mm; length of snout = 1.09mm; diameter of eye = 0.64mm; position of nasal pit = 0.36mm; position of first nostril = 0.42mm; size of first nostril = 0.07mm; position of second nostril = 0.91mm; size of second nostril = 0.14mm; total myomeres = 118; pre anal myomeres = 106; post anal myomeres = 12; origin of dorsal fin = 108^{th} myomere; dorsal fin rays = 40; origin of anal fin = 111^{th} myomere; anal fin rays = 19; caudal fin rays = 2+2; teeth = I+4+5 / I+7+2.

Moderately elongate leptocephali with a blunt pointed snout (Plate17. a) and a broadly rounded tail (Plate17. f); cleft of mouth oblique, curved, extending very much beyond the centre of eye; eye circular; nasal organ with well differentiated nostrils, posterior nostril placed slightly above the upper margin of eye; sharp, pointed dentition on each half of both jaws (Plate17. b): upper jaw has a slender, long, pointed tooth in the tip; four large teeth slightly decreasing in size follows of which the first tooth is curved and five small teeth in the posterior part; lower jaw bears a slender, upwardly curved tooth in the tip followed by seven equally sized large teeth and two slender comparatively small teeth; pectoral fin rudimentary (Plate17. d); dorsal and anal fins restricted to the posterior with the dorsal origin slightly ahead of the anal origin, both fins with discernible rays; caudal fin with indistinct hypurals and four distinct rays; alimentary canal a long, straight tube; anal opening at 106^{th} myomere.

Two pigment spots near the anterior margin of upper jaw; a cluster of pigment on the dorsal side of head; a few subcutaneous spots behind the eye (Plate17. c); a row of six pigment spots outlining the origin of gut near the base of pectoral fin (Plate17. c); widely placed pigment spots on the ventral side of the

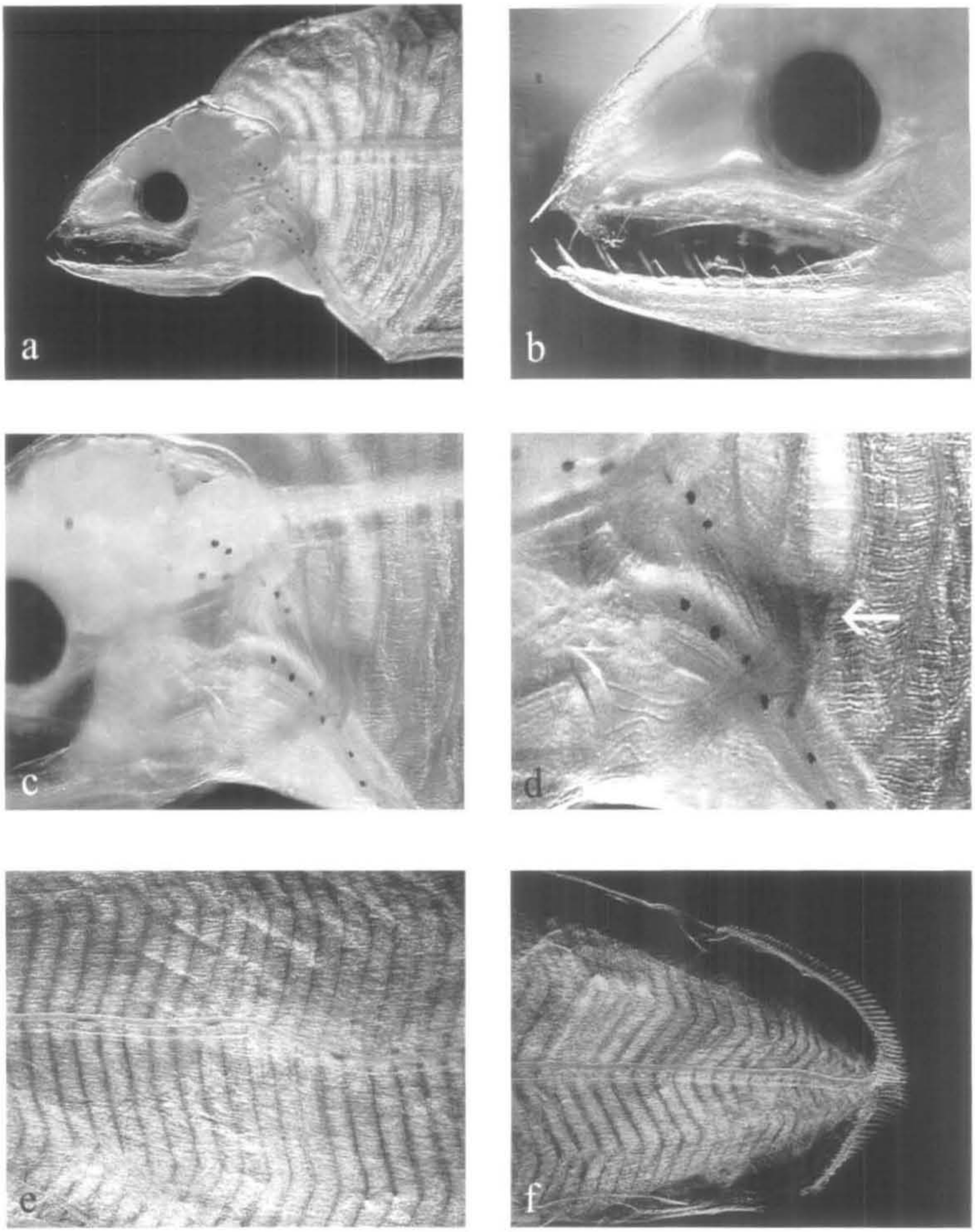


PLATE 17. Muraenidae- *Uropterygius* sp.
a. Head b. Teeth c. Pigmentation in the head region d. Pectoral fin e. Lateral pigmentation f. Tail

intestine, starting just ahead of the gastric region and continuing to the anal opening; lateral pigmentation in the form of 18 widely placed small internal patches on the mid line (Plate17. e); majority of the dorsal and anal fin rays with pigmentation; no pigments on caudal fin rays; single row of pigment spots on the mid ventral side lining the area between anal opening and anal fin origin.

Type A

Specimens examined = 2; total length = 41-53mm; maximum height (excluding vertical fins) = 8mm; length of head = 3mm; length of snout = 0.93mm; diameter of eye = 0.77mm; position of nasal pit = 0.25mm; position of first nostril = 0.25mm; size of first nostril = 0.14mm; position of second nostril = 0.85mm; size of second nostril = 0.14mm; total myomeres =118-120; pre anal myomeres = 75; post anal myomeres = 43; origin of dorsal fin = 31st myomere; dorsal fin rays = 310; anal fin rays = 190; caudal fin rays = 2+1; teeth = I+5+9 / I+7+4.

Elongate, broad body with rounded tips; head with convex dorsal profile (Plate18. a); snout, short, blunt and round; cleft of mouth oblique, slightly curved, reaching beyond the middle of eye; eye circular; anterior and posterior nostrils separate with the posterior nostril placed well above the upper margin of the eye; branchiostegal rays discernible (approx. 11) curving upwards over the opercular region; each half of upper jaw with an anterior clasping tooth followed by five large teeth decreasing in size posteriorly and nine small teeth; lower jaw bears single clasping tooth in its tip, seven long, slender, pointed teeth with a slight decrease in length posteriorly followed by four comparatively small teeth in its each half; a row of four distinct pores on the ventral side of lower jaw; upper jaw longer than lower jaw; pectoral fin very small with rudimentary rays; dorsal fin well developed with distinct rays, originating well ahead of anal fin; anal fin with distinct rays; caudal fin with three rays on the hypurals (Plate18. c); intestine straight with out any swellings; dorsal and ventral diaphanous zones becoming broader after the post anal region.

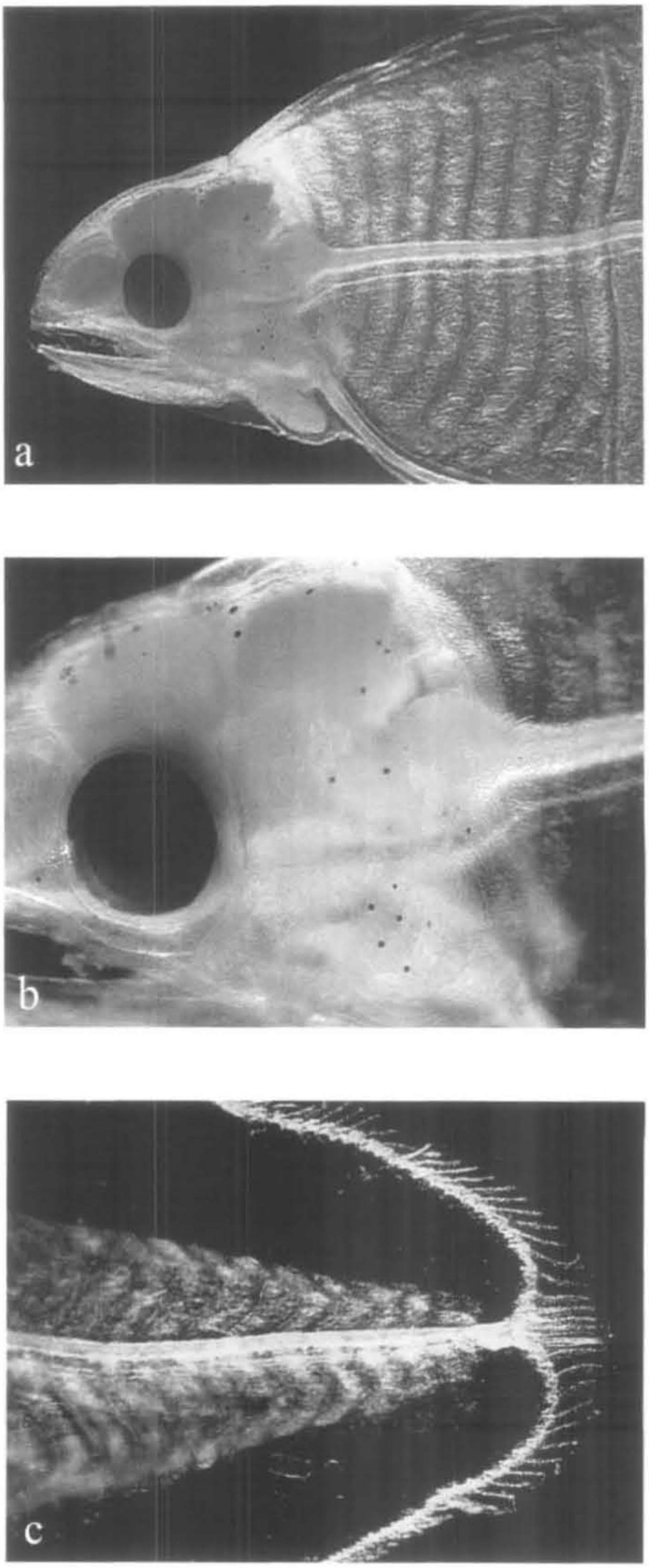


PLATE 18. Muraenidae- Type A
a. Head b. Pigmentation on head
c. Tail

A few pigment spots near the tip of upper jaw; scattered melanin pigment spots on the region of hind brain, behind eye and above the gill region (Plate18. b). Apart from this, the rest of the larva was with out any pigmentation.

Type B

Specimens examined = 1; total length = 62mm; maximum height (excluding vertical fins) =8mm; length of head = 4mm; length of snout = 1.06mm; diameter of eye = 0.9mm; position of nasal pit = 0.26mm; position of first nostril = 0.26mm; size of first nostril = 0.16mm; position of second nostril = 1.25mm; size of second nostril = 0.13mm; total myomeres = 135; pre anal myomeres = 79; post anal myomeres = 56; origin of dorsal fin 36th myomere; dorsal fin rays = 200; anal fin rays = 42; caudal fin rays = 3+2; teeth = I+4+7 / I+11.

Body elongate, spindle shaped with a bluntly pointed head (Plate19. a) and moderately round caudal fin (Plate19. e); blunt snout; cleft of mouth oblique, curved, reaching just beyond the centre of eye; posterior nostril very much above the upper margin of eye; circular eye; branchiostegals developed (more than 11) curving upwards above the opercular region (Plate19. d); upper jaw longer than lower jaw; even though the first clasping tooth is missing from then upper jaw its presence was evident, apart from this each half of the upper jaw bears four slender, acute teeth decreasing in size posteriorly followed by seven smaller teeth; lower jaw in its each half has a grasping tooth in the tip followed by eleven teeth gradually decreasing in size posteriorly (Plate19. c); pectoral fin in the form of a barely distinguishable, fleshy rudiment; opercular opening very much reduced; dorsal and anal fins with distinguishable rays; origin of dorsal ahead of anal; caudal with four distinct rays; intestine a long straight tube.

Melanin pigment spots scattered all over the head (Plate19. b), heart except lower jaw, giving the head a shaded appearance to the naked eye; a few stellate, branched chromatophores present near the anterior nostril, above and behind the eye;

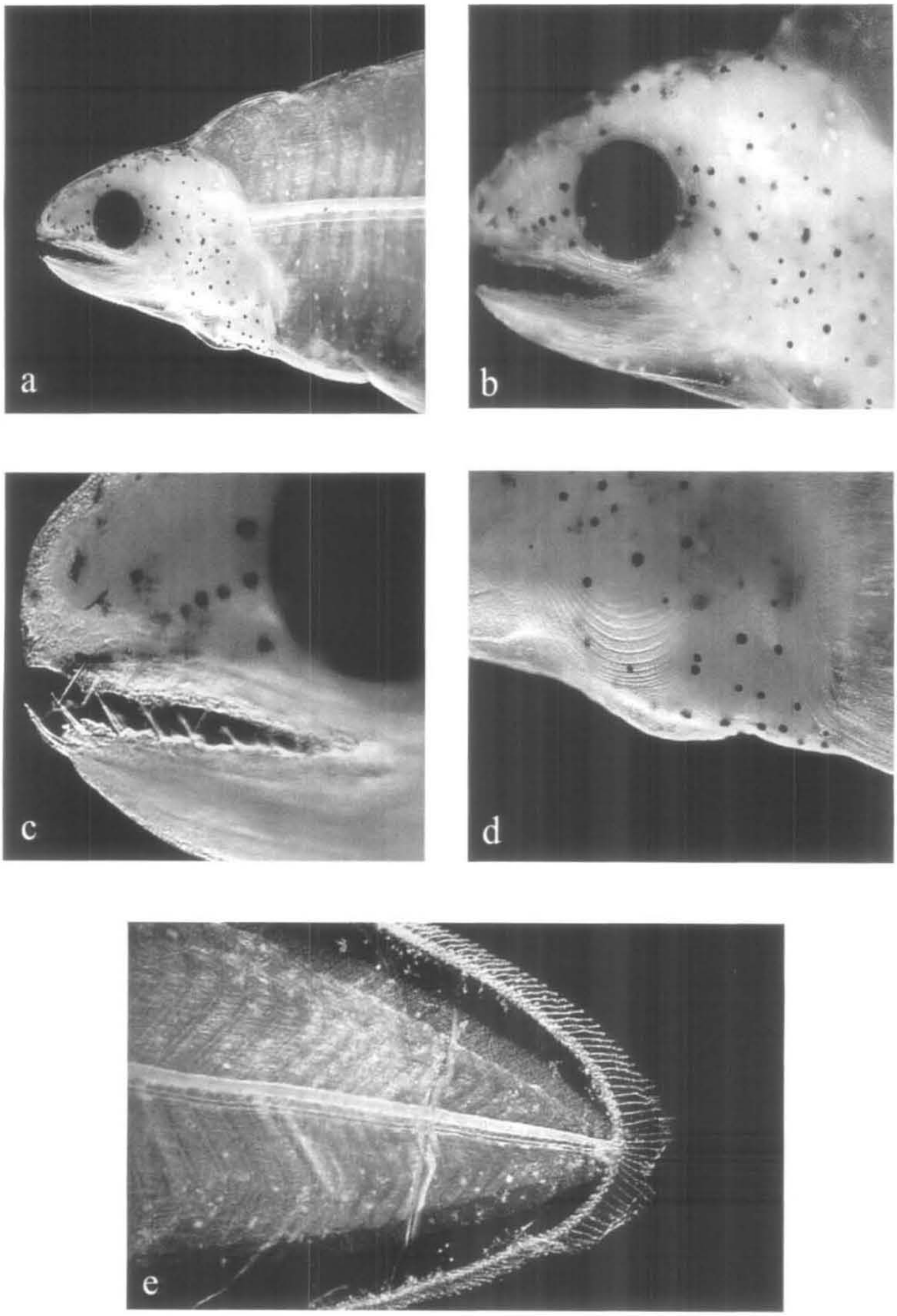


PLATE 19. Muraenidae- Type B
a. Head b. Pigmentation on head c. Teeth
d. Branchiostegal rays e. Tail

pigment spots on a few caudal fin rays and posterior most dorsal fin rays; majority of the anal fin rays with pigmentation; no dorsal, mid lateral or ventral pigmentation.

Type C

Specimens examined = 1; total length = 62mm; maximum height (excluding vertical fins) = 7mm; length of head = 3mm; length of snout = 0.91mm; diameter of eye = 0.7mm; position of nasal pit = 0.32mm; size of first nostril = 0.08mm; position of first nostril = 0.38mm; size of second nostril = 0.15mm; position of second nostril = 0.85mm; total myomeres = 141; pre anal myomeres = 79; post anal myomeres = 62; origin of dorsal fin = 58^{th} myomere; dorsal fin rays = 70; anal fin rays = 80; caudal fin rays = 3+1; teeth = I+4+4 / I+5+4.

Elongate body, tapering slightly towards head (Plate20. a) than tail; tail round; snout bluntly pointed; eye sub circular; cleft of mouth oblique, reaching beyond the centre margin of eye; nostrils separate, posterior nostril placed above the level of eye; upper jaw longer than the lower jaw; branchiostegals discernible (more than 10); a pore (an unidentified structure) between the nostrils on the dorsal margin of nasal pit; dentition (Plate20. b) on each half of the jaws as follows: upper jaw with a long, slender clasping tooth, four large, acute teeth, decreasing in size posteriorly followed by four small teeth; lower jaw bears an acute, upwardly curved tooth in its tip followed by five large teeth, the last being comparatively small than the preceding four and four smaller teeth on the posterior part; very small pectoral fin with rudimentary rays; dorsal and anal fins with distinct rays, dorsal fin originating ahead of the anal fin origin; caudal fin (Plate20. d) with four distinct rays.

Subcutaneous pigment spot on the margin of upper jaw and a few behind the eye; a slightly curved row of pigment spots on the posterior part of lower jaw ahead of heart, a few below the base of pectoral fin; scattered pigment spots on the ventral side of heart, which continues as a single row on the ventral side of gut anterior to the gastric region after which it shifts to the dorsal side of the intestine (Plate20. c) and continues to the anal opening; a mid dorsal row of pigments starting from the ninth

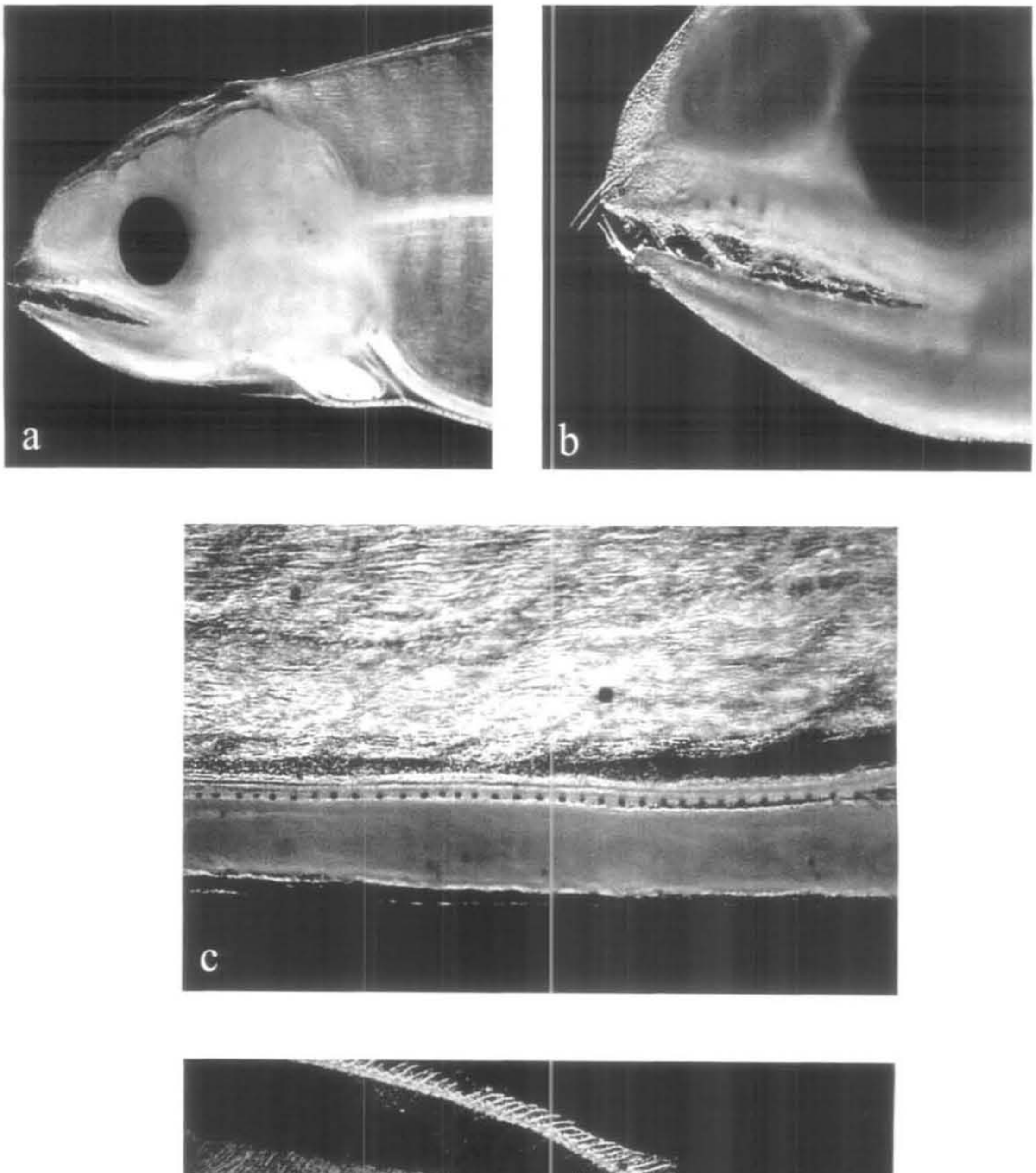


PLATE 20. Muraenidae- Type C
a. Head b. Teeth c. Pigmentation on head
d. Tail

myomere till the origin of dorsal fin; row of mid lateral , sub cutaneous pigment spots from head to tail; majority of dorsal and anal fin rays with pigments on its base; caudal fin rays with no pigmentation.

Family - Nemichthyidae

Nemichthyid leptocephali can be readily distinguished from those of other families by their relatively long and shallow body, depth about one-tenth to one-twentieth. Other characters that distinguish the Nemichthyid leptocephali are: tail moderate or attenuated; gut long and simple with out swellings or loops, anus near end of tail; head with a concave dorsal profile; snout sharp, peg like; dorsal fin short, beginning slightly before level of anus; pectoral fin present; nasal capsule small; small melanophores along top of gut posterior to gastric region, and on bottom of gut anterior to this point; lateral pigment when present, consisting of a few widely spaced spots below mid lateral line; internal melanophores along top of spinal cord extending length of body; maximum size 300-400 mm.

Type A

Specimens examined = 2; total length = 129-130mm; maximum height (excluding vertical fins) = 8mm; length of head = 6mm; length of snout = 2.53mm; diameter of eye = 1.34mm; position of nasal pit = 0.93mm; position of first nostril = 1.06mm; size of first nostril = 0.26mm; position of second nostril = 1.73mm; size of second nostril = 0.45mm; total myomeres = 216-217; pre anal myomeres = 148; post anal myomeres = 69; origin of dorsal fin = 94^{th} myomere; dorsal fin rays = 151; anal fin rays = 60; caudal fin rays = 4+3; teeth = I+I+9+11 / I+12+3

Body elongate; head with a long, sharp snout (Plate21. a); tail moderately attenuated; nasal organ well developed with separate nostrils; eye oval; cleft of mouth straight, oblique reaching not beyond the centre of eye; lower jaw marginally longer than upper jaw; pectoral fin circular with feeble rays; dentition prominent on both jaws (Plate21. b): upper jaw in its each half carries a short antero-dorsal tooth,

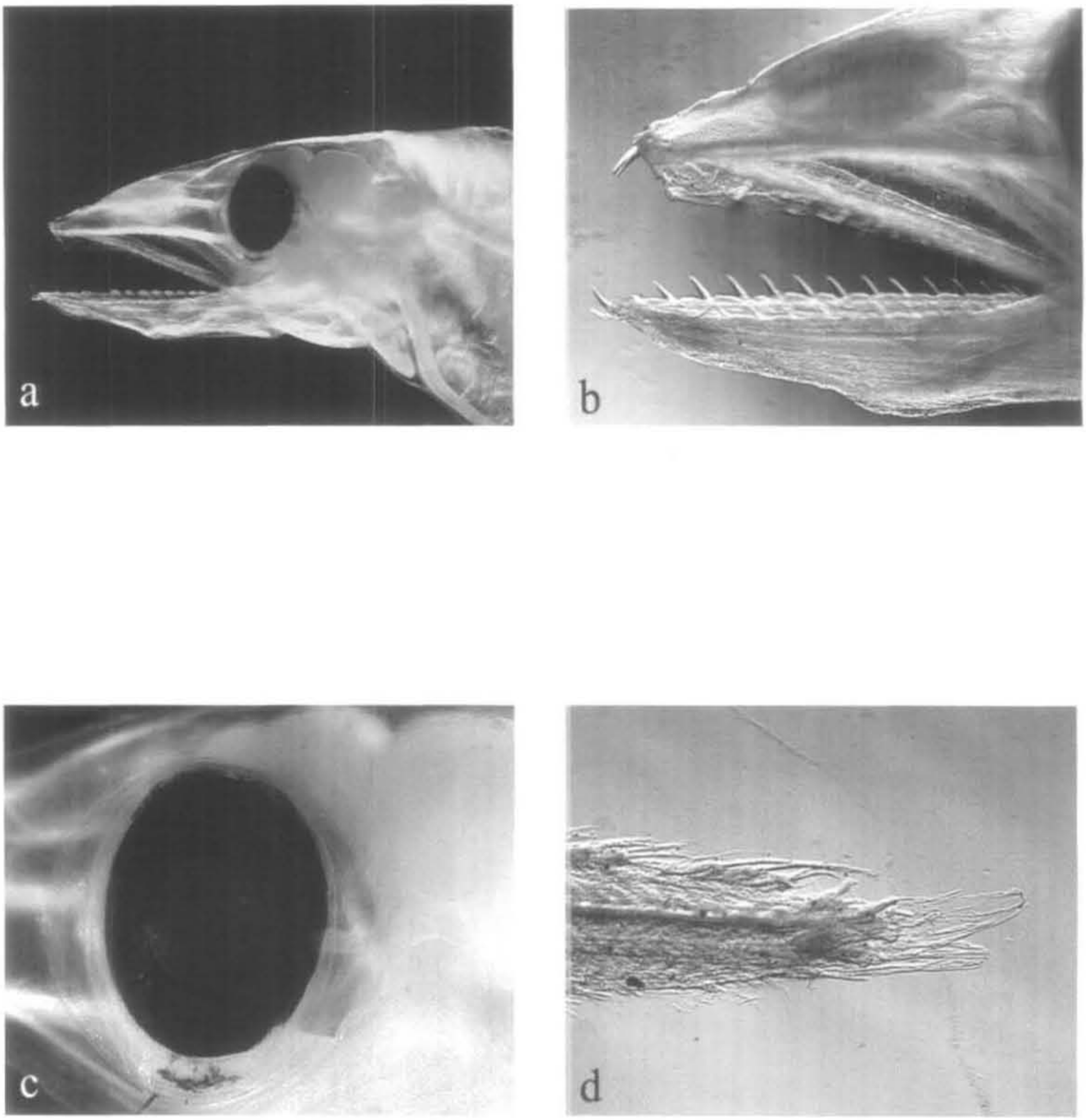


PLATE 21. Nemichthyidae- Type A
a. Head b. Teeth c. Pigmentation on eye
d. Tail

an acute clasping tooth, followed by nine large teeth and eleven small teeth; each half of lower jaw possesses an anterior curved tooth followed by twelve large teeth and three small teeth; dorsal and anal fins with only the posterior most rays well developed, the origin of dorsal fin ahead of the anal fin origin; caudal fin with long, well developed rays; hypurals distinct (Plate21. d); intestine long, with out loops or swellings, accounting to more than 3/4th the length of body.

A group of branched chromatophores below eye (Plate21. c); ventral pigmentation in the form of seven widely spaced, stellate' branched pigment patches of which the first four are present on the dorsal side of the intestine on both sides of body and the last three as a single row only on the ventral side of intestine; fin rays with out pigmentation; rest of the leptocephali with out pigmentation.

Type B

Specimens examined = 1; total length = 79mm; maximum height (excluding vertical fins = 7mm; length of head = 4mm; length of snout = 1.44m; diameter of eye = 0.86mm; position of nasal pit = 0.59mm; size of first nostril = 0.15mm; position of first nostril = 0.66mm; size of second nostril = 0.16mm; position of second nostril = 1.22mm; total myomeres = 194; pre anal myomeres = 105; post anal myomeres = 89; origin of dorsal fin = 57th myomere; dorsal fin rays = 167; anal fin rays = 77; caudal fin rays = 4+3; teeth = I+I+7+14 / I+9+8.

Body moderately elongate; head small (Plate22. a); snout sharp with a concave dorsal profile; tail moderately pointed; nasal organ with well developed and separate nostrils; cleft of mouth oblique and straight, reaching the center of eye; eye oval; pectoral fin oval; dentition (Plate22. b) on each half of upper jaw consists of a short antero-dorsal teeth, a long, clasping tooth followed by seven large teeth and 14 closely packed, short, slender teeth; lower jaw bears a clasping tooth in its tip followed by nine large teeth and eight small teeth in its each half; upper jaw marginally longer than lower jaw; dorsal and anal fins with only the posterior most

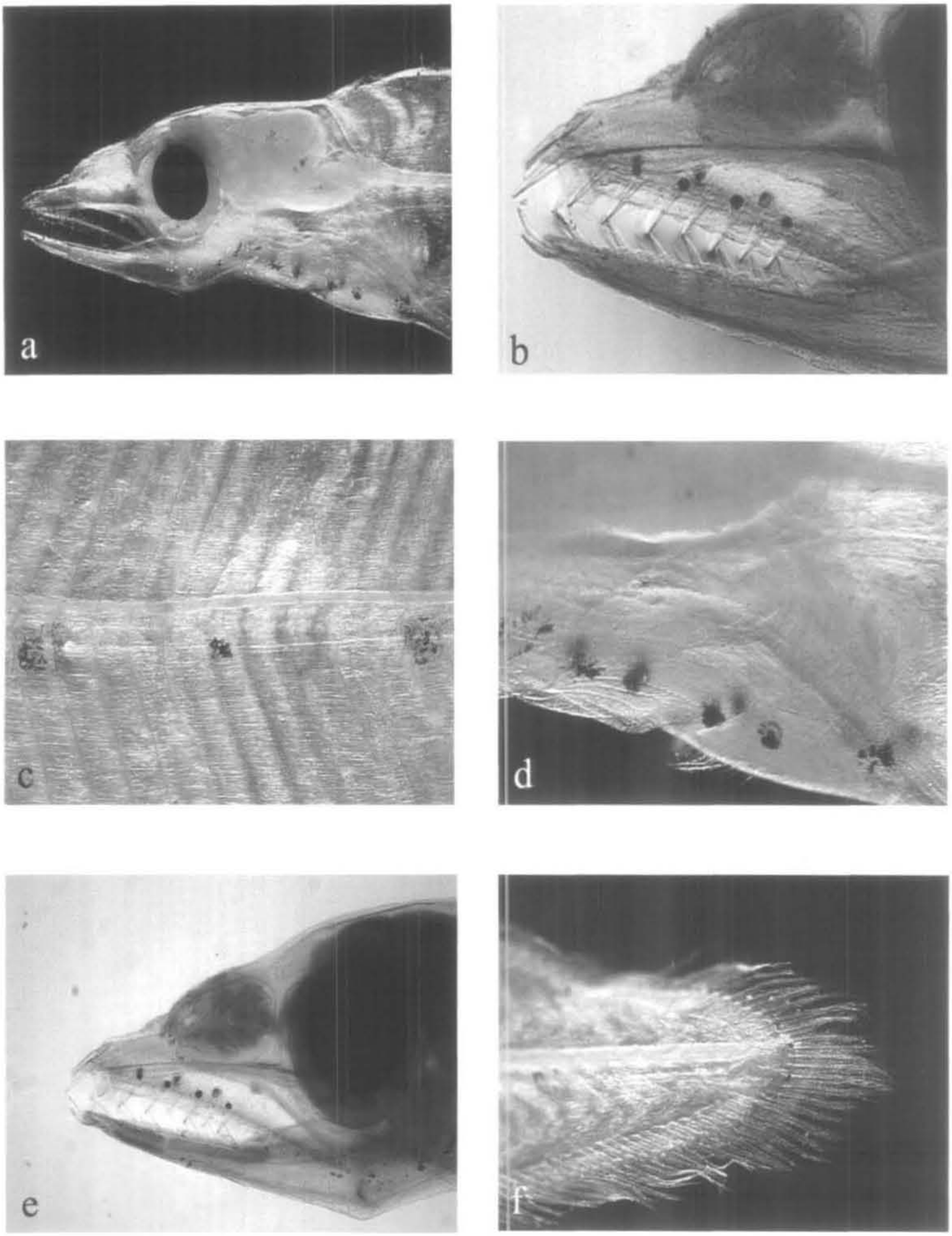


PLATE 22. Nemichthyidae- Type B
a. Head b. Teeth c. Lateral pigmentation
d. Pigmentation on heart region
e. Pigmentation on upper jaw f. Tail

rays discernible; caudal fin with well developed rays (Plate22. f); hypurals distinct; intestine straight with out loops or swellings, accounting for more than ½ the length of body.

The larva was with prominent pigmentation as follows: a row of pigment spots on the margin of upper jaw (Plate22. e); minute pigment spot below eye; two stellate, branched chromatophores on the posterior part of lower jaw ahead of heart; a few stellate chromatophores in and around heart region (Plate22. d); single, stellate, branched chromatophore below the base of pectoral fin; a row of stellate chromatophores on the ventral side of gut continuing till the anal opening; posterior to the gastric region another row of stellate chromatophores on the dorsal side of intestine, most commonly occurring on the right side than the left; 19 widely spaced, large, stellate chromatophores above the anal fin continuing to the tail; a row of 44 stellate, branched chromatophores just below the middle line (Plate22. c) from head to tail; a few posterior most dorsal fin rays with pigmentation; majority of anal and caudal fin rays with pigmentation on its base.

Family - Synaphobranchidae

The leptocephali of the family Synaphobranchidae can easily be identified from its "telescopic eye", which is the main distinguishing character. Other characters are: head variable, rostral filament some times present; gut about one-half to two-thirds standard length, with a series of thickenings; nasal organ closer to snout tip than to eye; ventral pigment a series of rather large melanophores; maximum size usually about 100mm (excluding the rostral filament), up to 200mm.

Type A

Specimens examined = 5; total length = 36-73mm; maximum height (excluding vertical fins) = 7mm; length of head = 5mm; length of snout = 2.46mm; diameter of eye (diameter of the stalked eye ball) = 0.5mm; position of nasal pit = 0.74mm; total myomeres =132-135; pre anal myomeres = 70; post anal myomeres = 64; origin of dorsal fin = 54^{th} myomere; teeth = I+I+? / I+3+6.

Broad, spindle shaped body, tapering to short, pointed tail and moderately elongate, slender head; snout very long, pointed (Plate23. a); cleft of mouth straight not reaching to the centre of the telescopic eye (Plate23. c); pectoral fin long with feeble rays; dorsal and ventral diaphanous zones slightly increasing in breadth after the post anal region; dorsal, anal and caudal fins with feeble, indistinct rays; nasal organ poorly developed; except for the antero-dorsal tooth and clasping tooth in each half of the upper jaw (Plate23. b), rest of the teeth has fallen off in the specimen examined; lower jaw on its each half carries an upwardly curved, slender clasping tooth originating very much below the tip followed by three large teeth and six small teeth; hypurals distinctly developed (Plate23. f); intestine more than half the length of body with six conspicuous and three less conspicuous thickenings (Plate23. e).

Pigment patch on the tip of upper jaw; pigment spot on the tip of lower jaw and also a long streak of pigment on its mid ventral side; single pigment spot on the posterior part of lower jaw and a small streak ahead of it; scattered pigment patches between the nasal organ and eye, below the eye ball and also behind it, on the region of hind brain; branched chromatophores anterior to the heart and below the base of pectoral fin; seven, branched, sub cutaneous chromatophores on the mid lateral line; a cluster of pigment spot near the caudal region; highly branched chromatophore on the ventral side of gut anterior to the gastric region, the same present along the intestine on all the thickenings (Plate23. d) including the one at the anal region; tip of the anus has a highly branched, stellate chromatophore; discontinuous pigmentation on anal fin; dorsal and caudal fins devoid of pigmentation.

Type B

Specimens examined = 1; total length = 37mm; maximum body height (excluding vertical fins) = 5mm; length of head = 5mm; length of snout = 2.46mm; total myomeres = 107; pre anal myomeres = 58; post anal myomeres = 49; teeth = I+I+2+11 / I+6+6.

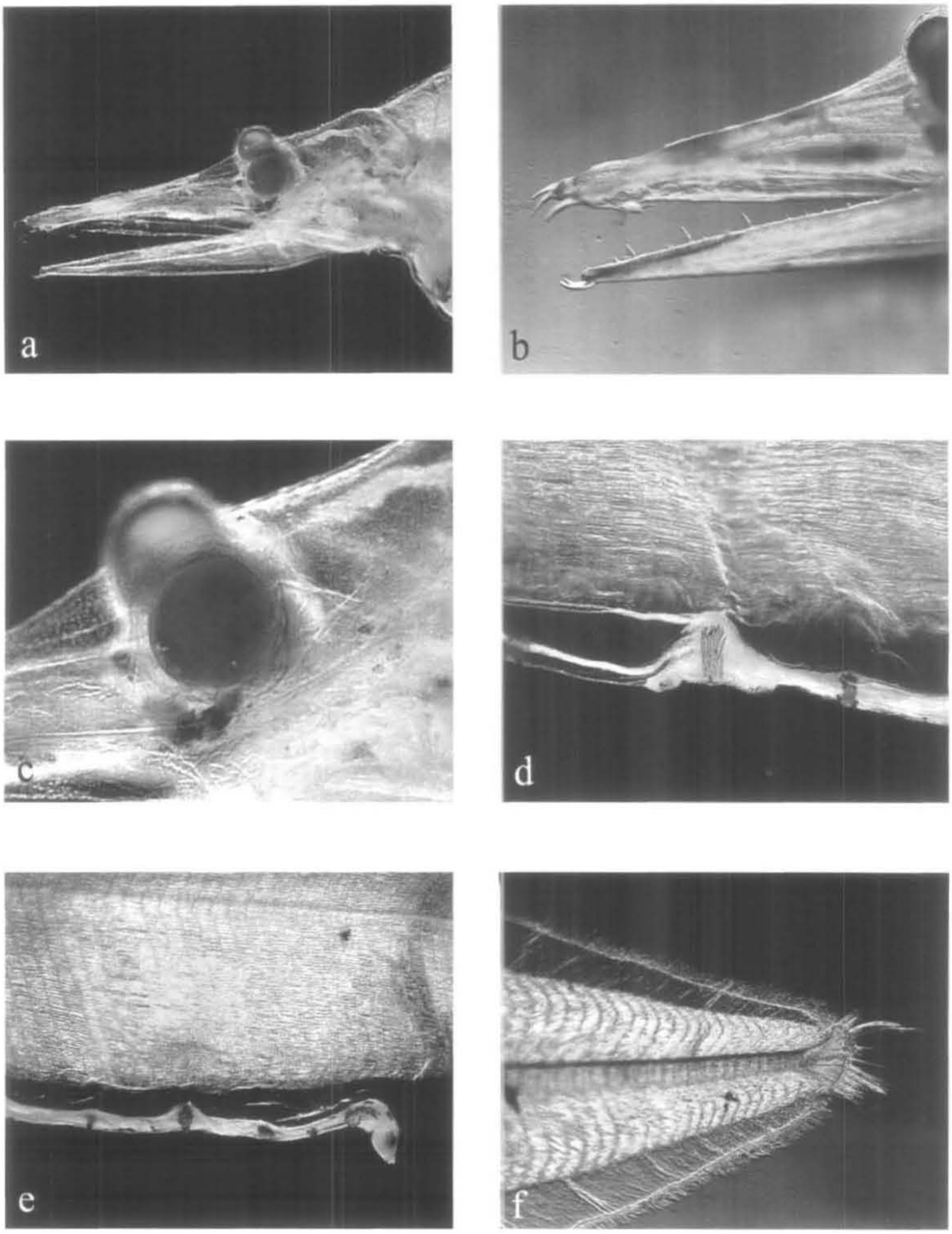


PLATE 23. Synaphobranchidae- Type A
a. Head b. Teeth c. Eye d. Pigmentation on intestine e. Intestine f. Tail

Body spindle shaped; head elongate (Plate24. a); tail moderately pointed; snout long and straight; cleft of mouth straight, not reaching to the level of eye; nasal organ not well developed; all fins except the caudal fin in the specimen examined was poorly developed, so unable to make any observations; caudal fin with discernible rays; eye telescopic (Plate24. b); dentition as follows: each half of upper jaw with a short, antero-dorsal tooth, a slightly curved, slender clasping tooth followed by two large teeth and 11 small teeth; lower jaw bears on its each half a curved, sharp tooth in its tip followed by six large teeth and six small teeth; intestine more than one-half of body length with seven swellings or thickenings (Plate24. f).

A few pigment spots on the anterior margin of the upper jaw; base of the stalked eye ball pigmented; five stellate, branching, sub cutaneous chromatophores behind the eye (Plate24. c); highly branching pigment network in and around the heart region (Plate24. d); single, stellate, branched chromatophore on the ventral side of gut ahead to the gastric region, another two between the first and second thickening and one each between the rest of the thickenings: branched, filiform chromatophores on all the seven thickenings (Plate24. e); 5-6 stellate, branched chromatophores were also present on the dorsal side of the thickening near the anus; hypurals well developed (Plate24. g).

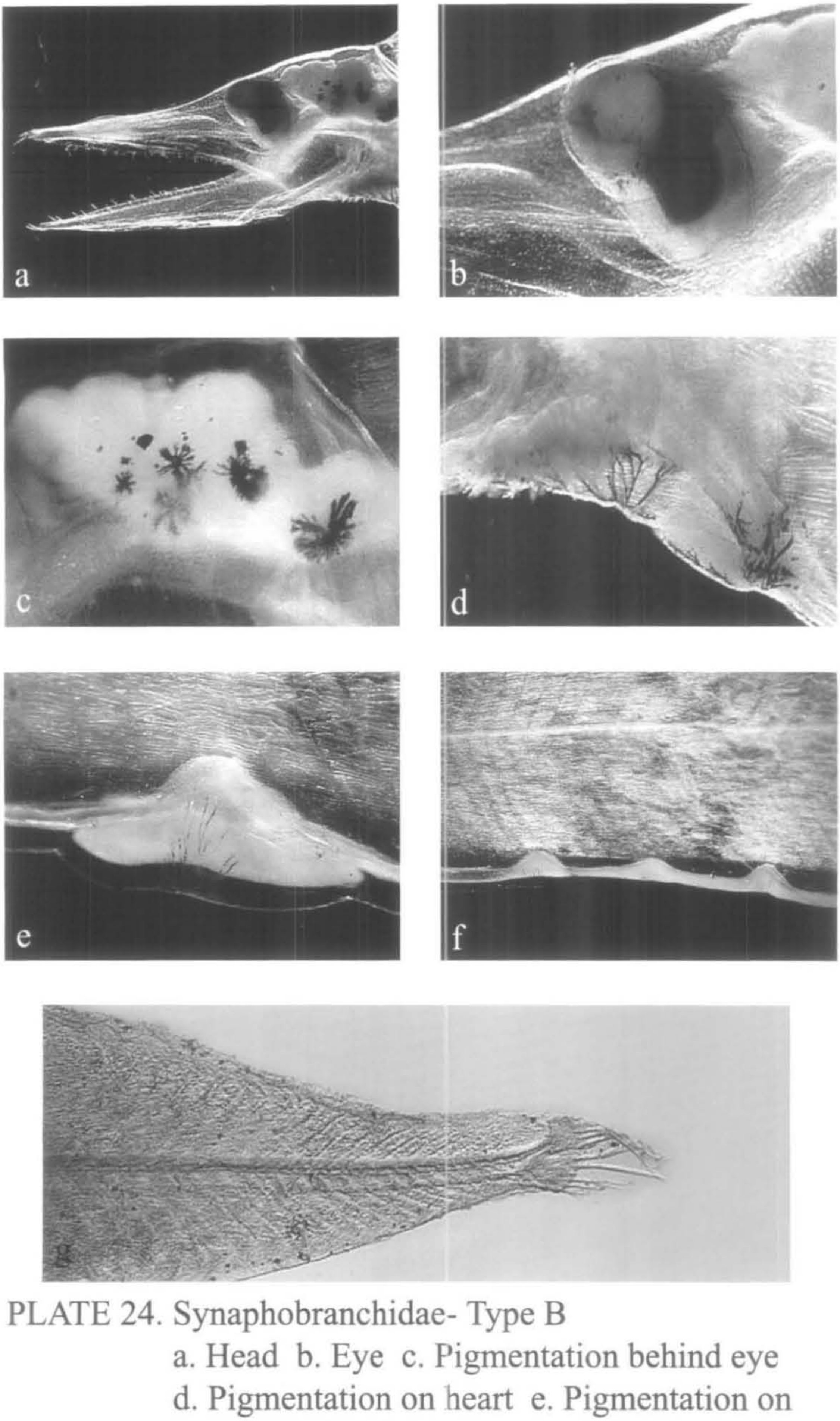


PLATE 24. Synaphobranchidae- Type B

a. Head b. Eye c. Pigmentation behind eye d. Pigmentation on heart e. Pigmentation on gastric region f. Intestine g. Tail

Metamorphosing stages of *Congrellus anago* (non Temm.and Schleg.)

The leptocephali of *Congrellus anago* (non Temm. and Schleg.) were first recorded from Indian waters by Gopinath (1946). The description was based on a collection of larval and post larval fishes found along the Trivandrum coast, south west coast of India. The same author (1950) described it again from the above area. Earlier works were based on the collections from the coastal waters, where as the present work is on the samples mostly from the deeper waters (>100m). So far no attempt has been made to study the metamorphosing stages of *Congrellus anago* (non Temm.and Schleg.) and the present study is based on the collection from the Deep Scattering Layer (DSL) of the south west coast of India. Metamorphosing stages are as described below:

Stage – A

The larva is long and transparent, measuring about 142mm in length. Maximum height of the body excluding the vertical fins is 13mm, which is 10.9 times in length. Head is comparatively short and is 35.5 times in length. Snout short, bluntly pointed and 2.9 times in head. Eye diameter 1.09mm, which is 3.6 times in head. Cleft of mouth oblique, straight not reaching the centre of eye. Jaws are provided with pointed, forwardly directed teeth. The dental formula is I+I+9+8 / I+9+4. Each half of the upper jaw with a short, antero-dorsal grasping tooth and a fang like long tooth. Other teeth are in two groups- first group of nine large teeth followed by eight small teeth in the second group. The lower jaw possesses a single large tooth in the tip followed by nine large teeth and four small teeth. Pectoral fin feeble with indistinct rays. Dorsal and anal fins short and restricted to the posterior, with both the fins originating from the same myomere. Dorsal fin has 29 rays and anal fins 31 rays. Caudal region bluntly pointed with 6 distinct rays. There are about 118 myomere in the body of which 108 are pre anal and 10 post anal. Intestine long and straight, extending to more than $3/4^{th}$ length of larva.

Pigmentation in the larva is very conspicuous. Single, mid dorsal row of stellate chromatophores starting from the 5^{th} myomere and continuing till the origin of dorsal fin. Lateral pigmentation in the form of minute melanophores outlining the myosepta immediately below the mid line forming a series of short, diagonal lines from head to tail. Closely packed chromatophores on the dorsal side of the intestine posterior to the gastric region, anterior to which it is on the ventral side of the gut. Single pigment spot below the heart on the anterior part. A few of the posterior most dorsal fin rays and the caudal fin rays have pigmentation on its base. Majority of the anal fin rays with pigmentation.

Stage – B

This is the growing stage of larva and there is a slight increase in the length and also the maximum body height. There is no predictable variation in the length of head. A slight decrease in the length of snout and an increase in the diameter of eye are noted. There are about 36 and 47 countable rays on dorsal and anal fin rays, respectively. Total myomeres in this stage is 114 with 104 pre anal myomeres, indicating the shifting of anus and 10 post anal myomeres. Origin of dorsal fin in this stage is one myomere behind the anal fin origin. Pectoral fin still with indistinct rays. Dental formula same as that of Stage A.

There is no change in the pigmentation of larva and it generally confirms with that of the previous stage, except for a few chromatophores (12-13) below heart.

Stage – C

This stage the larva has again shown an increase in the length though the height remains the same. There is no variation in the head length also. As in the previous stage there is a reduction in the snout length. Fin rays are distinct with 40 and 47 rays on dorsal and anal fins, respectively. Eye diameter is same as that of Stage A, showing a slight decrease from that of Stage B. Total myomeres as same as in the previous stage, of which 104 are pre anal in position. Except for three distinct pigment spot below the heart, pigmentation is same as in the earlier two stages.

Stage – I

This is the edentulous stage indicating the commencement of metamorphosis; the only noteworthy change from the last three stages is the complete shedding of all larval teeth. There is a slight increase in the height of larva than the previous two stages. Head length remains the same though there is a slight reduction in the snout length. There are about 117 distinct myomeres of which 101 are pre dorsal and 96 pre anal, indicating the shifting of dorsal fin and anus, respectively. There are about 60 and 93 rays on dorsal and anal fins.

Pigmentation of larva shows no variation and is almost the same as in the previous stages, except for the absence of pigments near the heart. The tail has become more tapering than that of earlier stages. The larva in this stage has the maximum length (165 mm).

Stage – II

A notable difference from that of the previous stage is the reduction in length (146 mm), which is a characteristic change during metamorphosis. There is a slight reduction in the height also. Dorsal, lateral and ventral pigmentations are same as in the earlier stages. Pigmentation on the base of all fin rays except for pectoral fin. Caudal region has become slightly opaque. Tail becoming more tapered with the anus and dorsal fin advancing forward. There are about 52 and 90 countable dorsal and anal fin rays, respectively.

Stage – III

This stage is again charaterised by the further reduction in length (132 mm), though the height and head length remaining the same as in the previous stage. This stage has the minimum snout length and there is a slight increase in the diameter of eye. There are about 112 myomeres, which is the minimum among all the stages. Dorsal fin and anus further shifting forwardly. There are about 61 and 102 dorsal and anal fin rays. Pectoral fin with indistinct rays. Seven branchiostegal rays discernible.

No trace of dorsal pigmentation noticed in this stage (might have fallen off, mention in the materials and methods). Lateral and ventral pigmentation same as in earlier stages. Pigmentation on all fin rays except the pectoral fin. Anus and dorsal fin has shifted forward. Thickness of the specimen has increased and the caudal region is opaque.

Stage – IV

This stage represents the smallest larva of all the previous stages with reduction in length (129 mm) and height (12 mm). There is a noticeable increase in length of head and also the shape has changed considerably. There is an increase in the length of snout and also in the diameter of eye. There are about 55 and 107 countable dorsal and anal fin rays. Total myomeres is 114 of which 76 are pre anal, further indicating the shifting of anus to a more anterior position. Dorsal fin origin also shifted anteriorly. Pectoral fin size slightly reduced. No trace of any adult dentition. Caudal region has become more tapered. Dorsal, lateral and ventral pigmentation present as in the earlier stages. Pigmentation on the base of dorsal, anal and caudal fin rays.

	Stage A	Stage B	Stage C	Stage I	Stage II	Stage III	Stage IV
Total length (mm)	142	149	159	165	146	132	129
Maximum height (mm)	13	14	14	15	13	13	12
Length of head (mm)	4	4	4	4	4	4	5
Length of snout (mm)	1.344	1.312	1.248	1.184	1.152	1.024	1.184
Diameter of eye (mm)	1.088	1.152	1.088	1.184	1.12	1.152	1.184
Caudal fin rays #	3+3	3+3	3+3	4+3	3+3	3+3	4+3
Dorsal fin rays #	29	36	40	60	52	61	55
Anal fin rays #	31	47	47	93	90	102	107
Total myomeres	118	114	114	117	113	112	114
Pre anal myomeres	108	104	104	96	87	80	76
Pre dorsal myomeres	108	105	104	101	95	92	89
Teeth	$\frac{I+I+9+8}{I+9+4}$	$\frac{I+I+9+8}{I+9+4}$	$\frac{I+I+8+8}{I+10+2}$	Nil	Nil	Nil	Nil

 # Only distinct rays counted

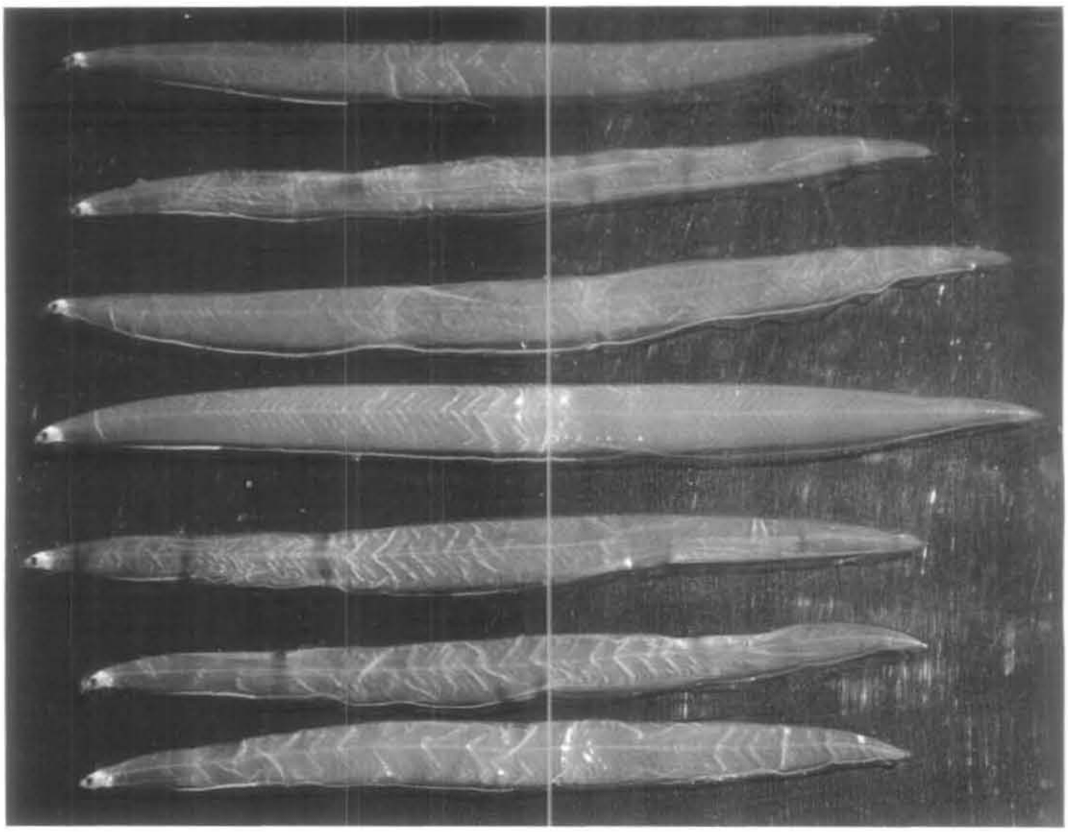


PLATE 25. Metamorphosing stages of *Congrellus anago* (non. Temm. and Schleg.)

Distribution and abundance of Leptocephali

Quantitative abundance of Leptocephali

The general observation made on the occurrence and abundance of the leptocephali showed that numerically they formed one of the major components of the nekton in the Deep Scattering Layer (DSL). Leptocephali were found distributed extensively all along the west coast of India. It was present in 148 IKMT stations (81 night and 67 day) out of a total of 172 IKMT stations sampled in the west coast of India during the period from May 1998 to June 2001. The location of stations (day and night) from where leptocephali were obtained is given in Fig.5. The quantitative estimates have been made as number per1000m^3 of water. The occurrence of leptocephali varied from a low of 0.04 to a maximum of 18.32. no./1000m^3 per haul. Comparatively the night biomass was high (154.95) than the day (57.32). In general, the night and day biomass constituted 73% and 27%, respectively, of the total biomass (212.27) on the west coast of India.

Geographical variation

The leptocephali were found distributed widely in the west coast of India from the coast to the deep sea. They are distributed evenly (below 5/1000m^3 for one degree square) with three high density pockets (above 5) as shown in Fig.6. The highest abundance of 18.32 was recorded from the area 12°30 – 71°29. Only five stations yielded more than ten. The next abundance of 5 – 10 were observed only in 9 stations. The rest of the catch was below five. The important areas of abundance in the regions where the catch per haul was more than 5 numbers are given in Table 1.

Latitudinal abundance

The whole area investigated was divided into latitudes from 6° - 21°N. In general it was found that the leptocephali numerical abundance was more pronounced in 15° - 19° N. Another good concentration was located in 8° - 10°N and

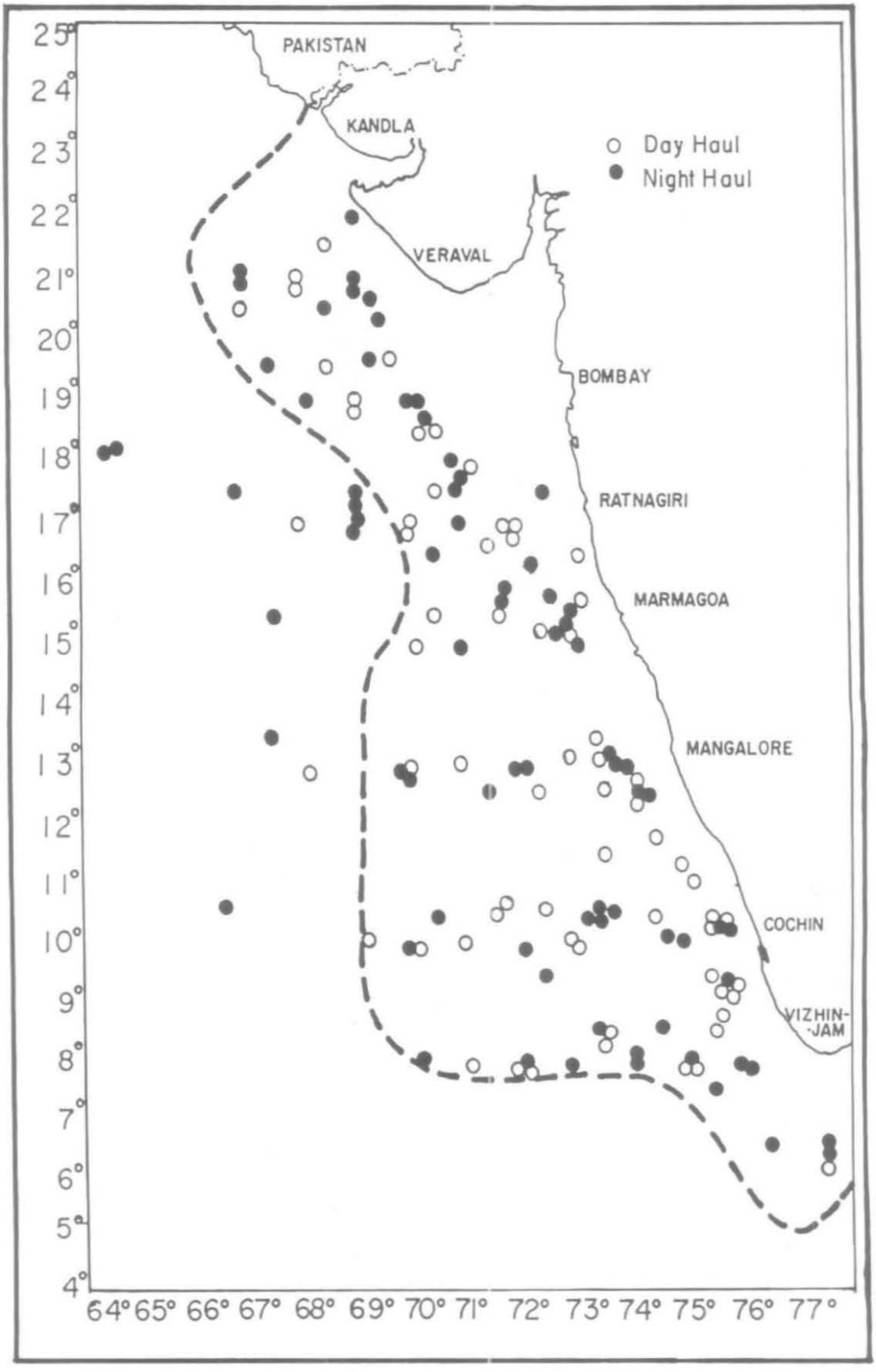


Fig: 5 I K M T Stations in the West Coast of India

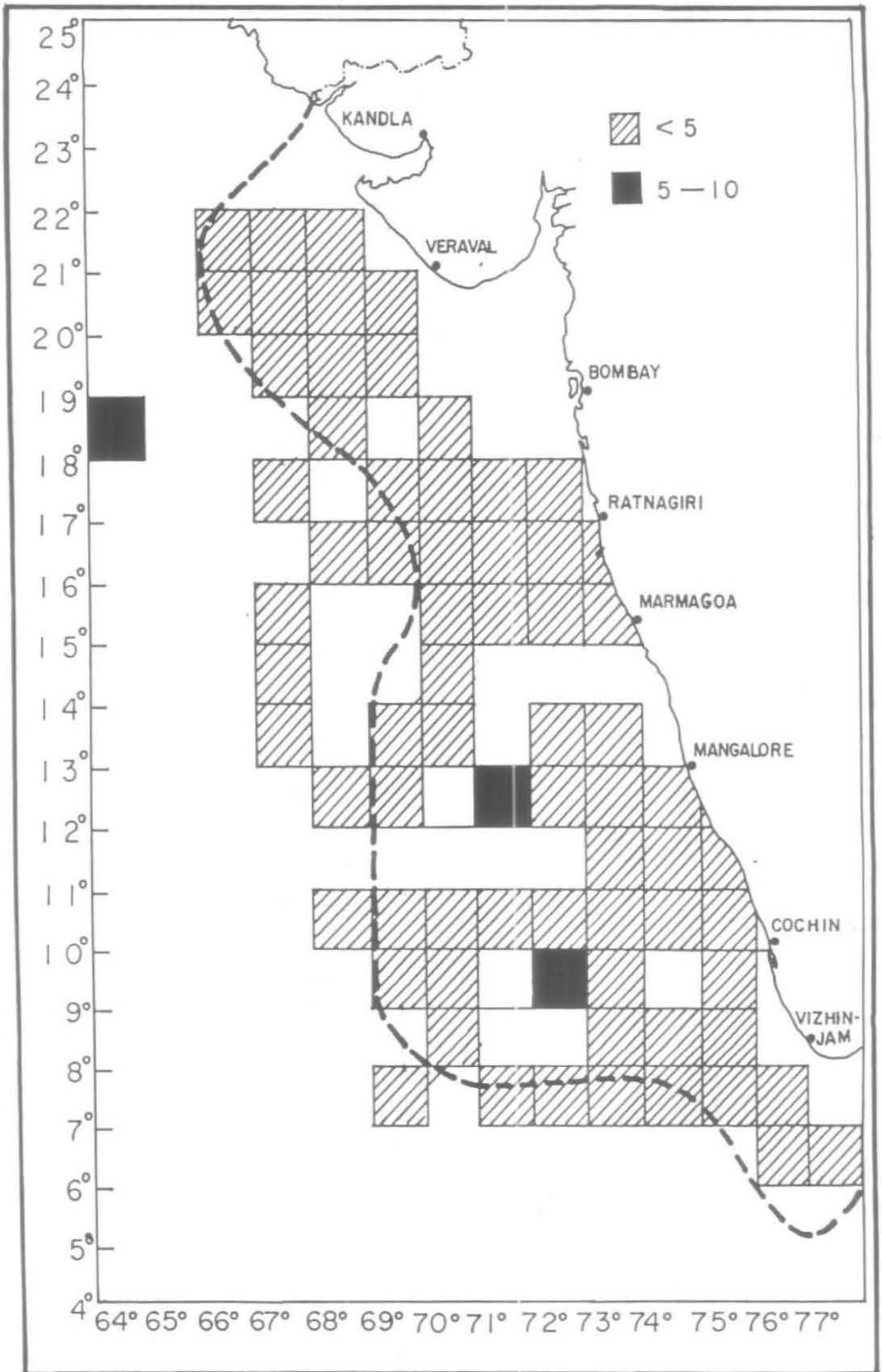


Fig. 6 Distribution and abundance of Leptocephali (No /1000 m^3) in the West-coast of India

Table 1: Major area of abundance of Leptocephali in the West coast of India

Station No.	Area of operation	Latitude	Longitude	Depth of operation (m)	Depth of bottom (m)	No. of Leptocephali	No./1000m^3
116	SW	12^0 30	71^0 29	60-70	1584	509	18.32
17	SW	9^0 29	72^0 30	70	1810	373	13.42
503	NW	18^0 59	70^0 00	50	254	331	11.92
21	SW	10^0 29	73^0 30	10	1926	279	10.04
101	NW	18^0 07	64^0 35	30-145	1603	279	10.04
499	NW	16^0 59	71^0 51	185	227	242	8.71
2	NW	17^0 23	69^0 30	60	3359	223	8.03
158	NW	19^0 33	69^0 20	35	1182	215	7.74
497	NW	17^0 00	70^0 00	320	3476	189	6.80
104	NW	18^0 27	70^0 30	40-80	332	184	6.62
504	NW	19^0 00	68^0 58	320	2809	182	6.55
149	NW	17^0 30	70^0 59	10-20	1741	150	5.40
103	NW	18^0 23	70^0 10	40-80	1345	140	5.04
138	NW	15^0 19	72^0 52	15-35	229	140	5.04

also in 12°N (Fig.7). Latitude wise the leptocephali maximum was recorded in 18°N (4.06) off Bombay followed by 19° and 17°N (3.47 and 2.74).

Day – night variation

A comparative study of the day and night variation of leptocephali was carried out in the entire area of investigation. The analysis revealed that 27% of the total leptocephali collected was taken during day while the night samples took a share of 73% there by showing more than three times number of leptocephali in the day samples.

a) Latitudinal variation

The night catch was comparatively high in most of the latitude with a range of 32.74% to 96.15%. The highest percentage of 96.15 was recorded at 9° latitude followed by 88.96% at 12° latitude. In the day it was 16° latitude that had the highest percentage (67.26%) and the lowest by 9° latitude (3.85%). The latitude wise abundance in numbers for day and night are presented in Fig.8.

b) Month wise abundance

The monthly catch percentage varies from a low of 7.3% to a high of 92.68%. Figure 9 shows that the night catches constituted for the bulk of the catch. It shows a variation from a low value of 34.41% (March) to a high of 92.68% (May). In the day it was the month of May with a lowest share of 7.32% and a highest share of 65.59% in March. (Fig.9)

c) Vertical abundance

The vertical abundance of leptocephali was maximum during night in the operational depth range of 50 – 100m (89.26%) where as a low of 23.30% in the 100 – 300m range. The daytime abundance indicates a very low of 10.74% in the 50 – 100m depth of operation and a high at 100 – 300m (76.70%). (Fig.10) The leptocephali were present up to a depth of 750m.

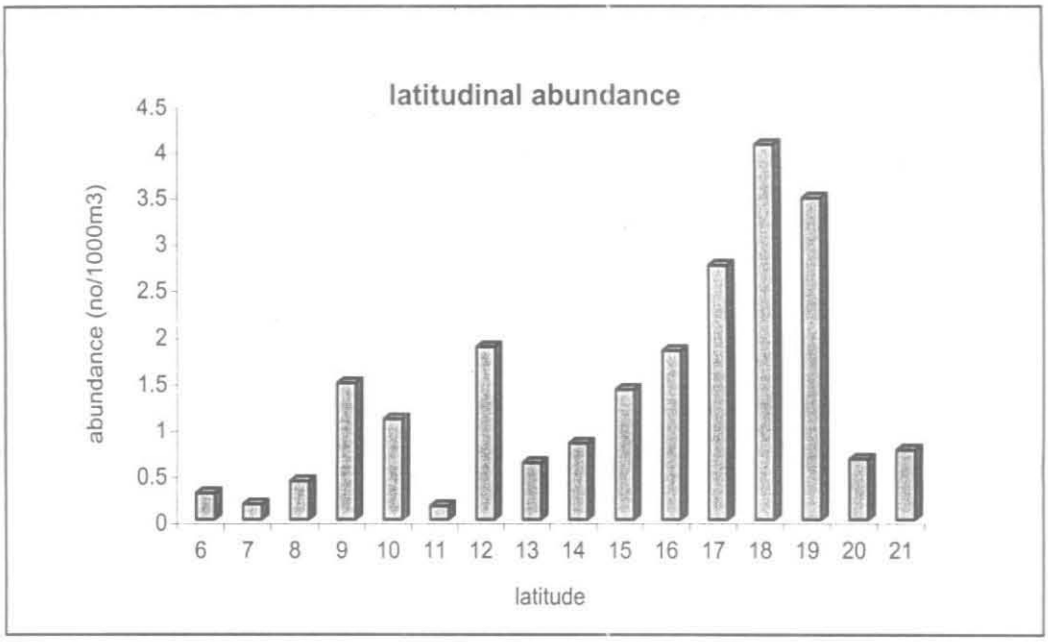


Fig. 7. Latitudinal abundance of Leptocephali in the west coast of India

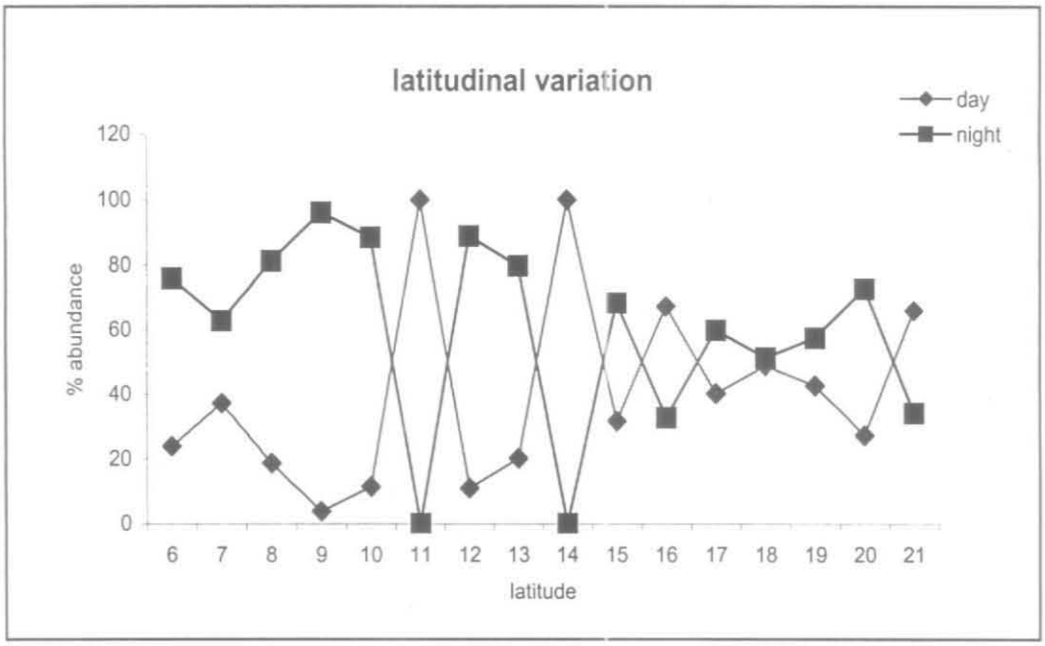


Fig. 8. Latitudinal variation (day and night) of Leptocephali

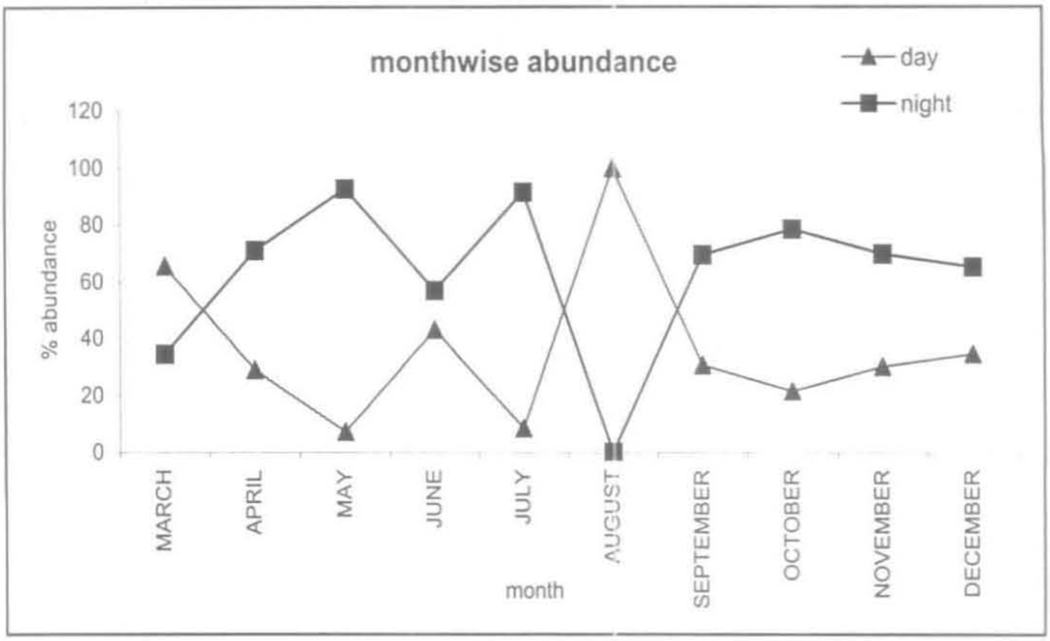


Fig.9. Month wise abundance (day and night) of Leptocephali

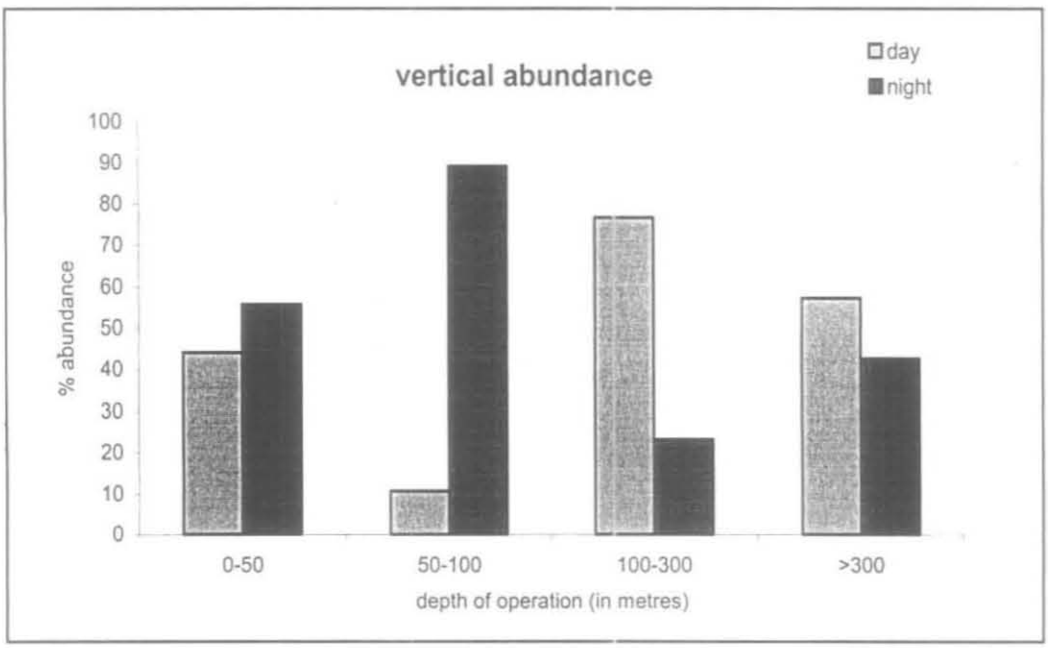


Fig.10. Vertical abundance (day and night) of Leptocephali

d) Horizontal abundance

The analyses of the samples revealed an increasing trend up to the 1000 – 3000m depth zone (77.70%) during night, after which it decreases. The nighttime catch showed a lowest figure in the 0 – 200m depth zone (33.64%). The day catch was low between 1000 – 3000m and recorded a high value of 66.36% in the 0 – 200m depth zone. (Fig.11)

e) Diurnal variation

The leptocephali were maximum during the early hours of the day (00 00 – 04 00Hrs), which accounted for the bulk of the catch (51%). It was followed by 16% between 20 00 – 00 00Hrs and 12% between 04 00 – 08 00Hrs. Rest of the day's hauls constituted to less than 10% of the total abundance (Fig.12).

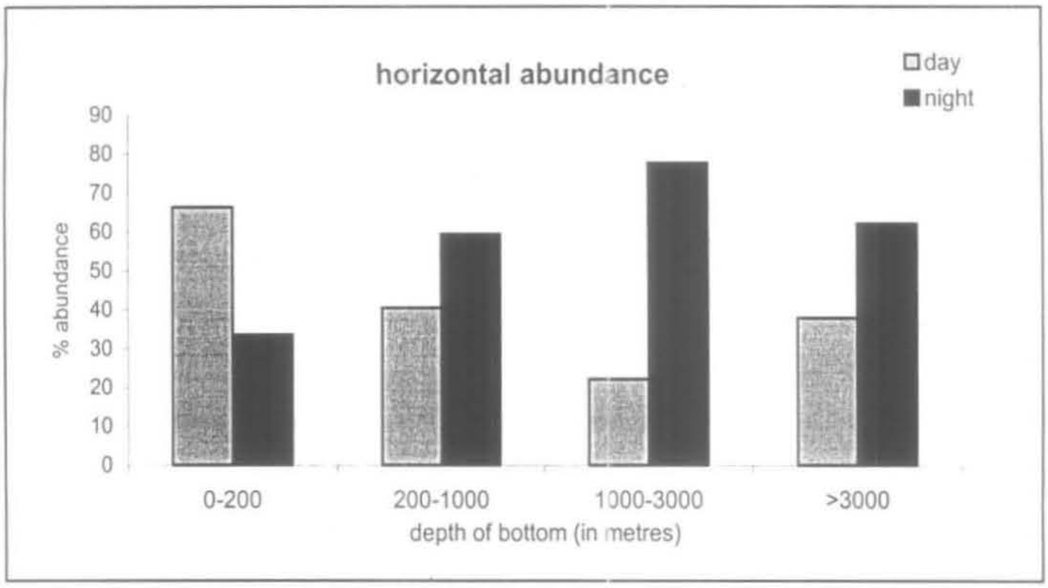


Fig.11. Horizontal abundance (day and night) of Leptocephali

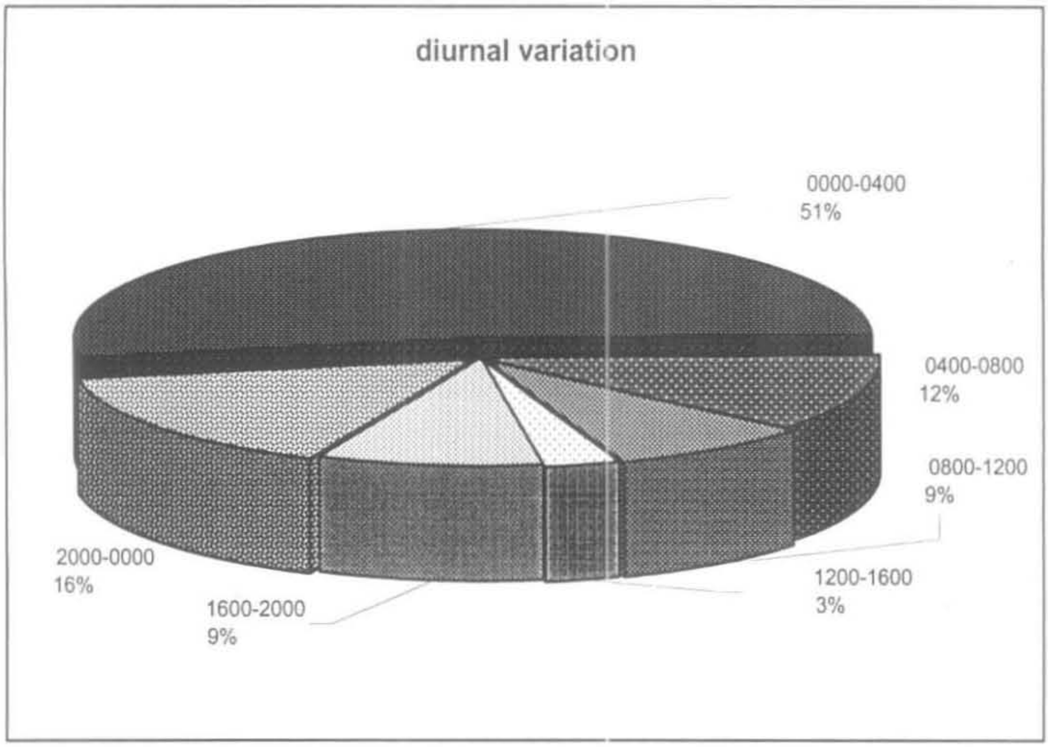


Fig.12. Diurnal variation of Leptocephali

Distribution and abundance of major families of Leptocephali in the southwest coast of India

The resource distribution and abundance of leptocephali of the west coast of India was dealt in the previous section, where as, this section deals with the leptocephali of the southwest coast of India. The study was carried out in an area below 15°N latitude and 78°E longitude. A total of 105 IKMT operations were carried out of which 84 were positive stations (80%) for leptocephali. The maximum number per haul per $1000m^3$ was 18.32 at 12°30N latitude and 71°29E longitude and with an average of 0.91 numbers. Leptocephali belonging to five major families constituted the IKMT samples from the south west coast of India viz. Congridae, Ophichthidae, Muraenidae, Nemichthyidae and Synaphobranchidae.

The numerical abundance of leptocephali in the south west coast of Indian EEZ shows that the maximum number was contributed by the family Congridae (44%) followed by Ophichthidae (30%) and the rest by other three families and some unidentified specimens coming under the order Anguilliformes, Elopiformes (Fig.13). The total biomass ($no/1000m^3$) of the south west coast (76.09) accounted to about 35.85% of the total west coast leptocephali. In general, the leptocephali distributed evenly in the south west coast of India with a catch of <5 number and having only two pockets of more than 5 (5-10) at off Cochin and off Mangalore (Fig. 6).

Latitude wise distribution clearly indicates that the leptocephali were most abundant in 12° latitude (average 1.87 number). Generally 9°-12° latitude contributed about 82% of the catch. Table 2 shows the percentage of their numerical abundance in the south west coast.

Seasonal abundance was more during monsoon with an average of 5.84 number. Numerically the catch was better during May (44.75%), followed by July (27.86%). The monthly catch (in number) percentage is presented in Table 3.

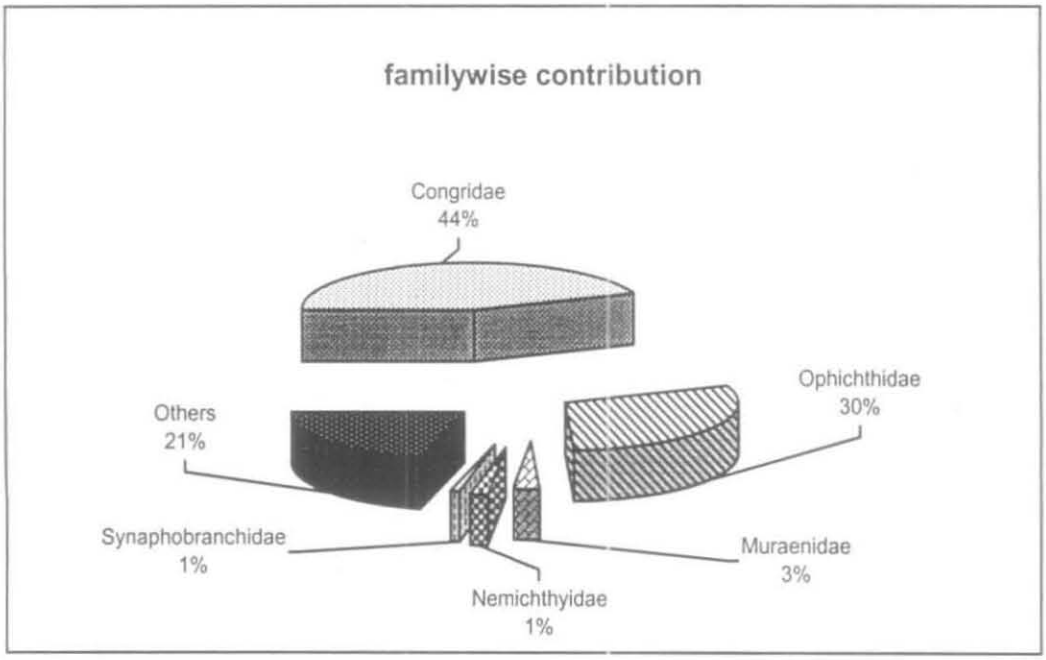


Fig.13. Family wise percentage contribution

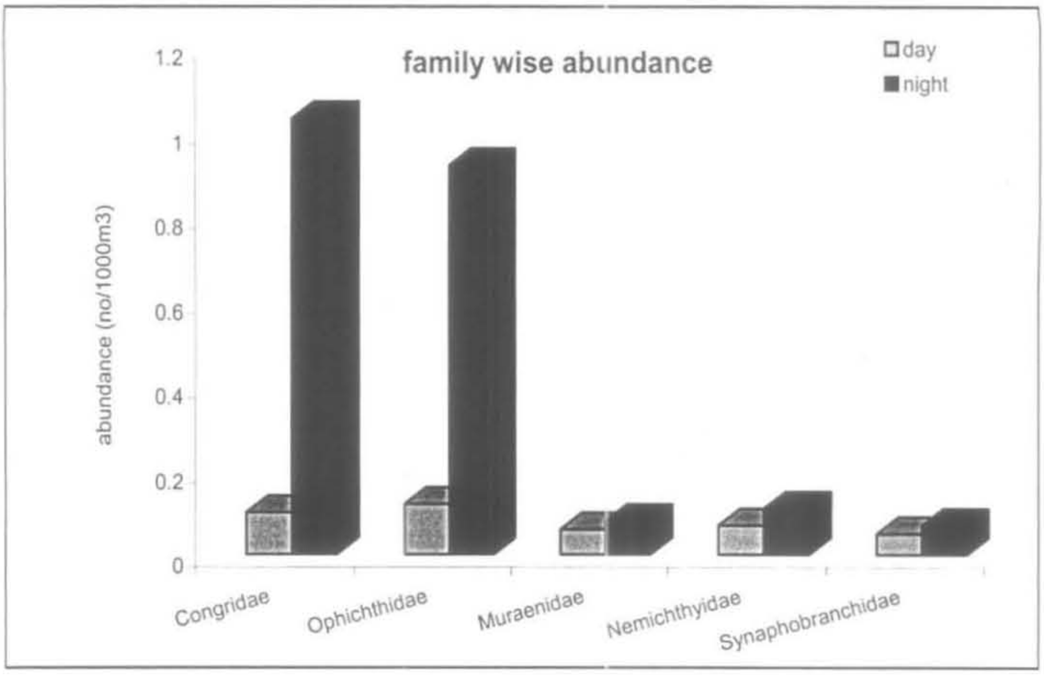


Fig.14. Day and night abundance of different families of Leptocephali

Table 2. Latitude wise abundance

Latitude	% Abundance
6	1.51
7	2.98
8	5.53
9	19.49
10	29.94
11	0.76
12	31.93
13	5.68
14	2.18

Table 3. Monthly abundance

Month	% Abundance
April	2.84
May	44.75
June	1.47
July	27.86
September	4.59
October	5.25
December	13.25

Table 4. Vertical abundance (day and night)

Depth of Operation (m)	% Abundance Day	% Abundance Night
0-50	3.90	96.10
50-100	6.07	93.93
100-300	74.05	25.95
>300	66.47	33.53

Table 5. Horizontal abundance (day and night)

Depth of Bottom (m)	% Abundance Day	% Abundance Night
0-200	100	0
200-1000	30.20	69.80
1000-3000	7.98	92.02
>3000	40.85	59.15

The numerical abundance of leptocephali in the vertical depth range (depth of operation) shows that it was more on the 50 – 100m depth range (59.87%), where as the horizontal distribution was maximum in the depth zone between 1000 – 3000m (82.97%). In general, a 24hour period abundance of leptocephali shows a maximum abundance between 20 00 – 00 00 hours in the southwest coast of India.

Day-night variations

Day and night variations in the catches were very clear, with the night catch contributing a major share of 87% (66.2) and day a meager 9.89 accounting to only 13 % of the total. Diurnal variation also shows that the night catches were more pronounced for the two families viz. Congridae and Ophichthidae (Fig.14). The night catch of the family Congridae constituted about 92.11% of the total congrid catch and Ophichthidae forming 92.86% of the total ophichthid catch. Day and night variations for the other three families viz. Muraenidae, Nemichthyidae and Synaphobranchidae were less in comparison with the values less than 0.2 numbers.

a) Latitudinal variations

Latitude wise variations in the day and night catch (percentage) shows that the night catch was maximum in general with the 9° latitude contributing the highest (94.42%) followed by 12° and 6° with 92.74% and 90.63%, respectively. The general trend shows that the night catch was comparatively high in comparison with little variation. The day catch was low with a maximum of 39.68% in the 7° latitude (Fig. 15). In latitudes 11° and 14° the night catch was nil as there was no IKMT operation.

b) Monthly variations

A study of the monthly day-night variations in catch shows that the month of May contributed to the highest percentage of the night catch (93.76%) followed by July (91.51%). The day maximum was in the month of September with a share of

43.30% (Fig.16). General trend shows that the night catch contributed to more than 50% of the total catch in each month.

c) Vertical abundance

The depth wise (depth of operation) percentage contribution of the day and night shows that the night contribution was high in the depth range of 0 – 50m with a share of 96.10% followed by 50 – 100m (93.93%) (Table.4). The day was high in the 100 – 300m depth range. The figure (Fig.17) shows that the leptocephali was abundant in the depth up to 100m during night and in 300 – 400m during day. It was found in a maximum depth of 750m. A higher numerical abundance of 279, 509 and 273 numbers were found with in the depth range of 75m.

d) Horizontal abundance

Diurnal variation studies along the different bottom depths show that the depth zone of 1000 – 3000m contributed the maximum night catch (92.02%), where as the daytime contribution was high above the 3000m zone (Table 5).

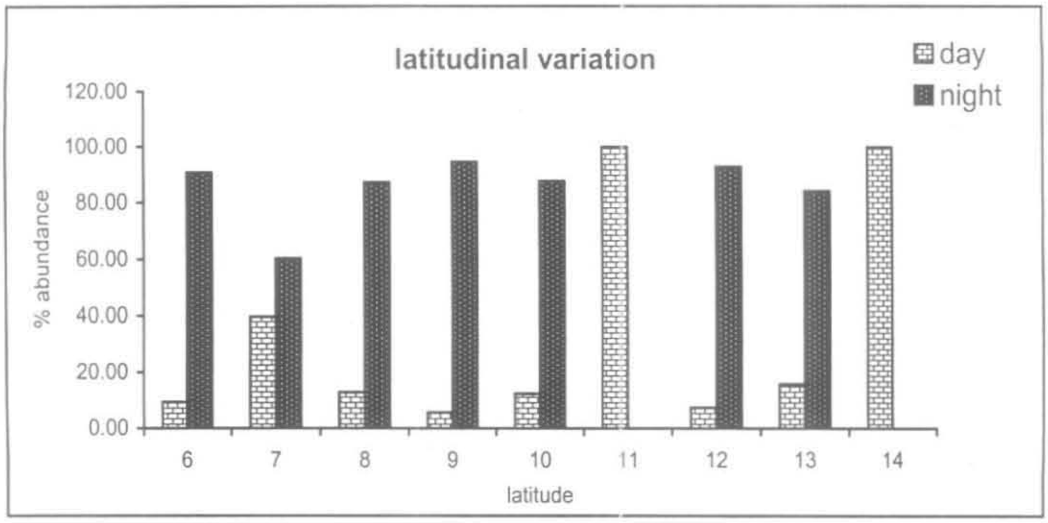


Fig. 15. Latitudinal variation (day and night) of leptocephali in the southwest coast of India

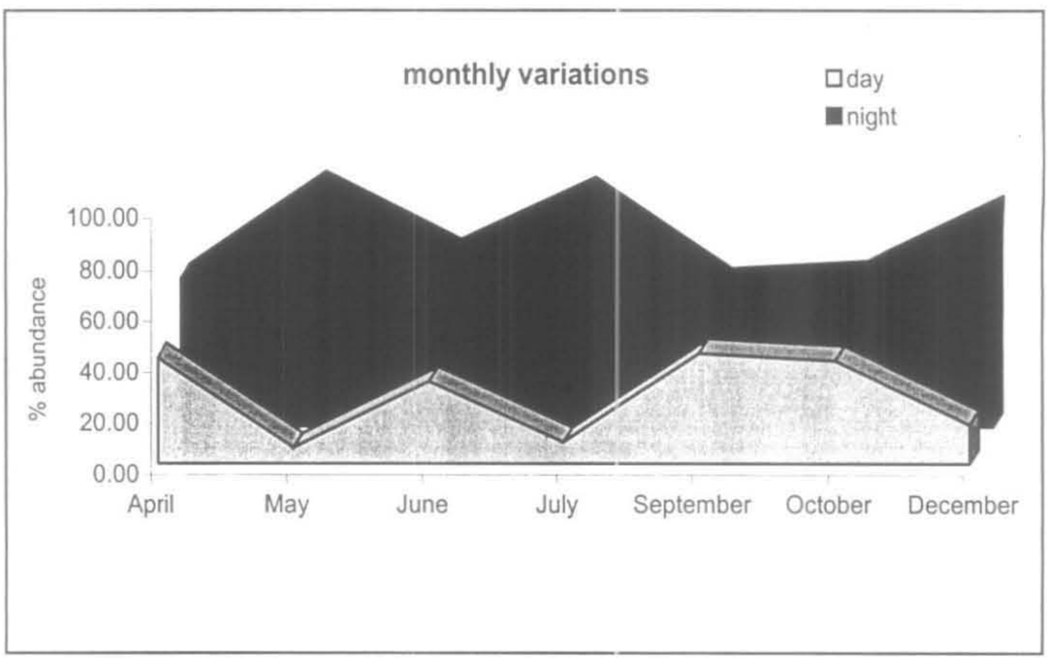


Fig.16. Monthly variation (day and night) of leptocephali in the southwest coast of India

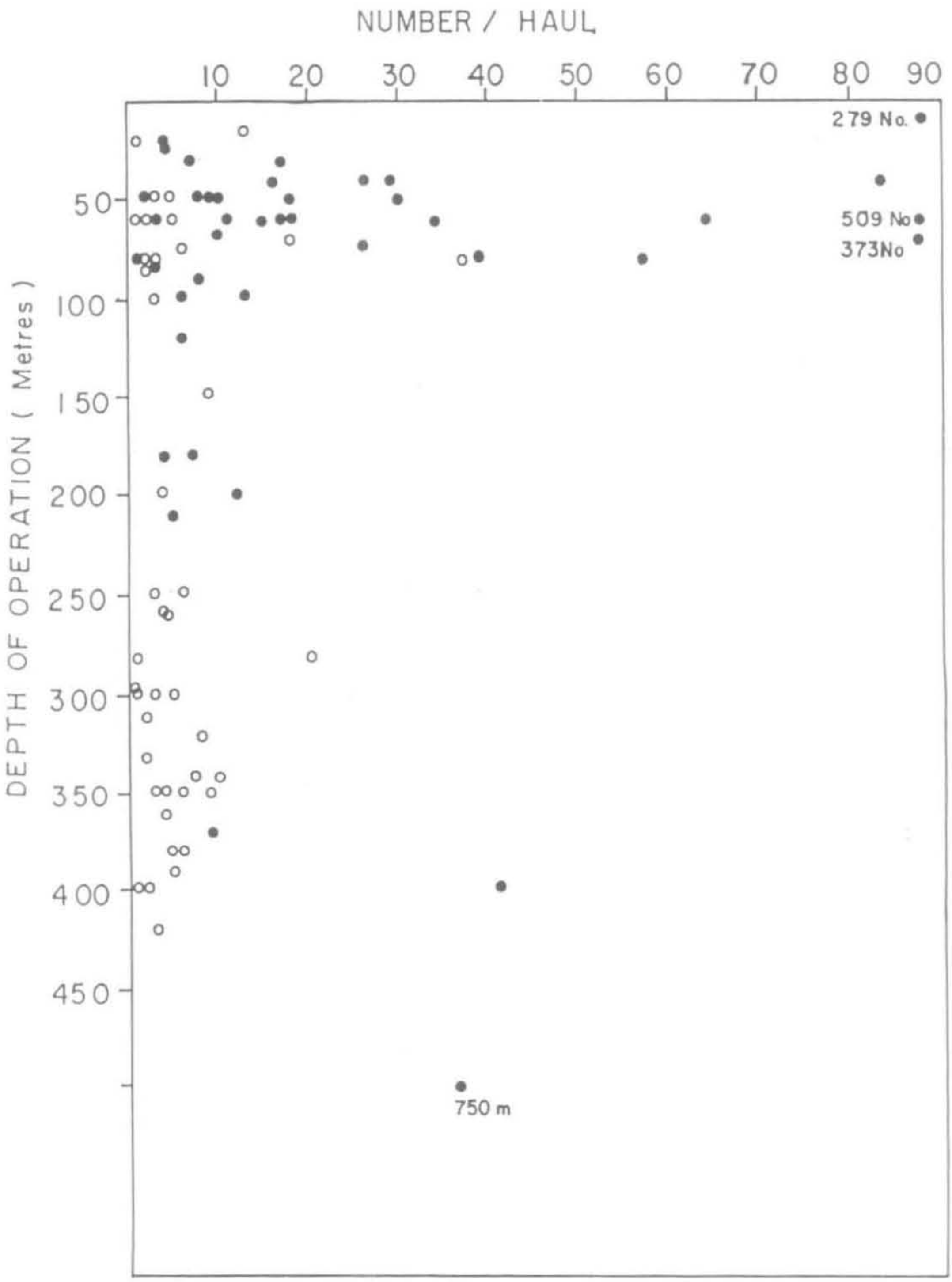


Fig: 17 Distribution (Day & Night) of Leptocephali (No. / haul)
in the South West Coast of India

Family – Congridae

Leptocephali of the family Congridae formed the largest group among the five families in the south west coast of India. It was present on 57 stations out of the 84 stations sampled in the area of study accounting to about 44% of the total southwest coast leptocephali. It was distributed evenly with one dense pocket off Cochin. (Fig.18)

Latitudinal abundance clearly reveals that the congrid leptocephali was mainly concentrated in the two latitudes viz. 9° and 10° (79.18%) with a maximum in the 10° accounting to 40.45% of the total Congridae catch in the south west coast of India. (Table 6)

Monthly catch proposition shows that the bulk of the catch was made during May, which contributed, to about 80.04% of the total congrid catch, followed by July (8.48%). (Table 7)

The percentage abundance of congrid leptocephali in the different depths of operation is given in Table 8. It clearly indicates that the maximum concentration in the depth ranges of 0-50m and 50-100m, with the 50-100m depth range contributing the major share (55.90%).

Studies on the horizontal distribution (Depth of Bottom) of the family Congridae revealed that the maximum abundance was between the 1000-3000m depth zone which contributed 93.03% of the congrid catch. It was also noted that there was a complete absence of this family in the 0-200m depth zone. (Table 9)

Diurnal variation studies show that the congrid leptocephali were abundant maximum during the late night hours (20 00 – 00 00hours) with a percentage contribution of 82.19%.

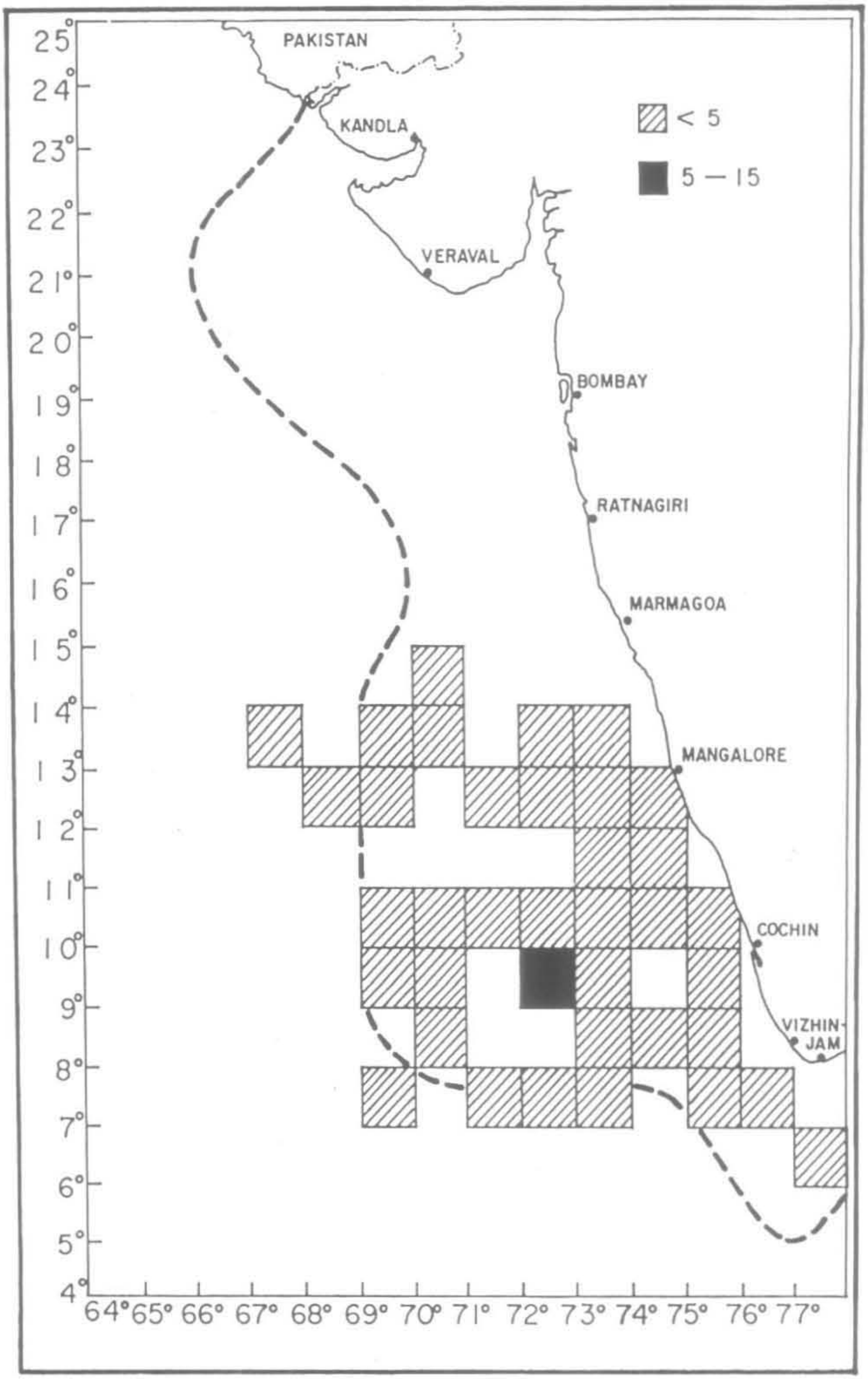


Fig: 18 Distribution and abundance (No/1000m^3) of Congridae in the South West coast of India

Table 6. Latitude wise abundance

Latitude	% Abundance
6	0.54
7	2.79
8	4.61
9	38.73
10	40.45
11	1.50
12	9.44
13	1.39
14	0.54

Table 7. Month wise abundance

Month	% Abundance
April	0.64
May	80.04
June	1.82
July	8.48
September	2.58
October	0.43
December	6.01

Table 8. Vertical abundance

Depth of Operation (m)	% Abundance
0-50	39.27
50-100	55.90
100-300	1.72
>300	2.90

Table 9. Horizontal abundance

Depth of Bottom (m)	% Abundance
0-200	0
200-100	2.15
1000-3000	93.03
>3000	4.83

Day-night variation

a) Latitudinal variation

The study revealed that the night catch was fairly high in comparison along the different latitudes. The share of the night catch was contributed maximum from the 9° latitude (98.34%), followed by 10° latitude with a share of 94.16%. The contribution to day catch was more at the 13° latitude (30.77%). (Fig.19)

b) Monthly variation

The monthly catch statistics shows a variation of 2.41% to 97.59% in the day-night composition. Results of the studies revealed that the month of May accounted for the maximum contribution to the night catch (97.59%), followed by December (82.14%). A general trend shows maximum catch during the night. Daytime contribution was maximum during the month of April (83.3%). (Fig.20)

c) Vertical distribution

A comparative study of the day and night distribution of congrid leptocephali along the different depths of operation revealed that the night catch was maximum at the depth range of 50 – 100m forming 96.35%, followed by 0-50m range (95.63%) (Fig.21). The day catch was maximum in the depth range above 300m (92.59%). The study also revealed a marked increase in the catch during night from 0 – 50m to 50 – 100m, after which it shows a declining trend. Figure 22 show that the congrid leptocephali was concentrated more, especially in the night, within the 100m range with a maximum of 243 and 351 numbers in two instances. The congrid leptocephali were present to a maximum depth of 420m.

d) Horizontal variation

The analyses revealed a complete absence of congrid leptocephali in the 0 – 200m bottom depth zone. Diurnal variation studies showed that the major share of the night catch was represented by the 1000-3000m depth zone (94.93%) where as, that of the day catch was 60% by 200 – 1000m. (Fig.23)

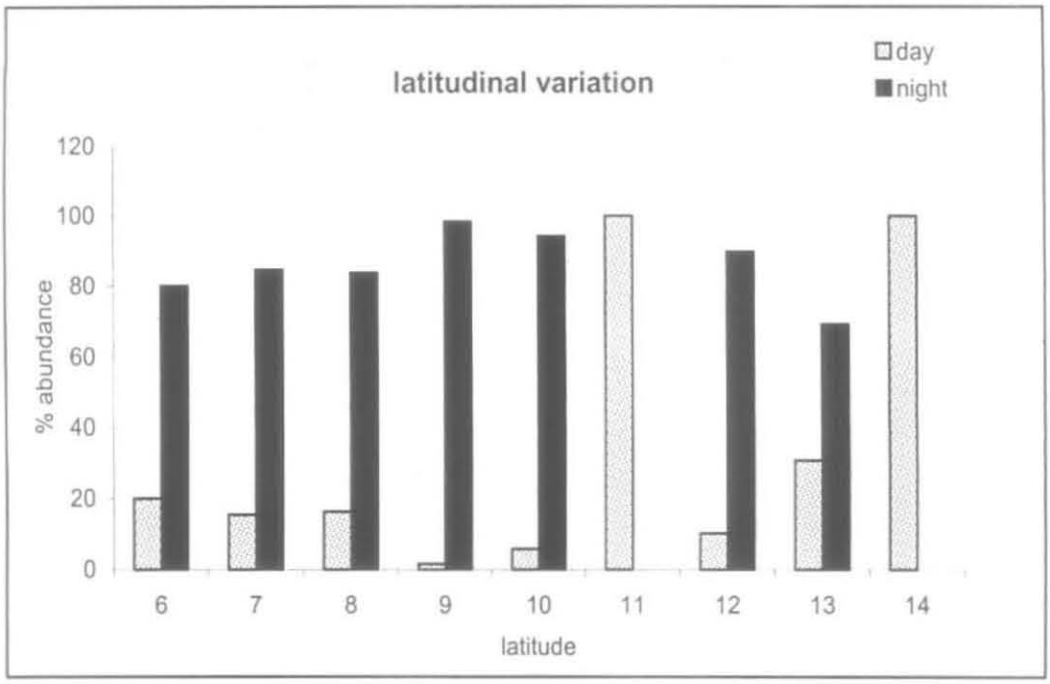


Fig.19. Congridae – latitudinal variation (day and night)

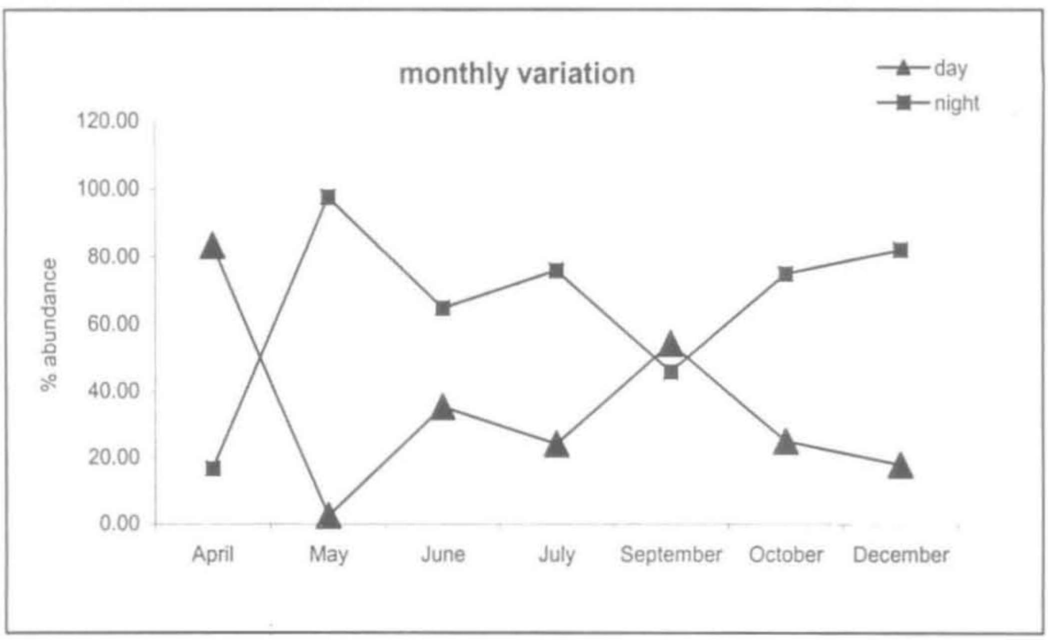


Fig.20. Congridae – Monthly variation (day and night)

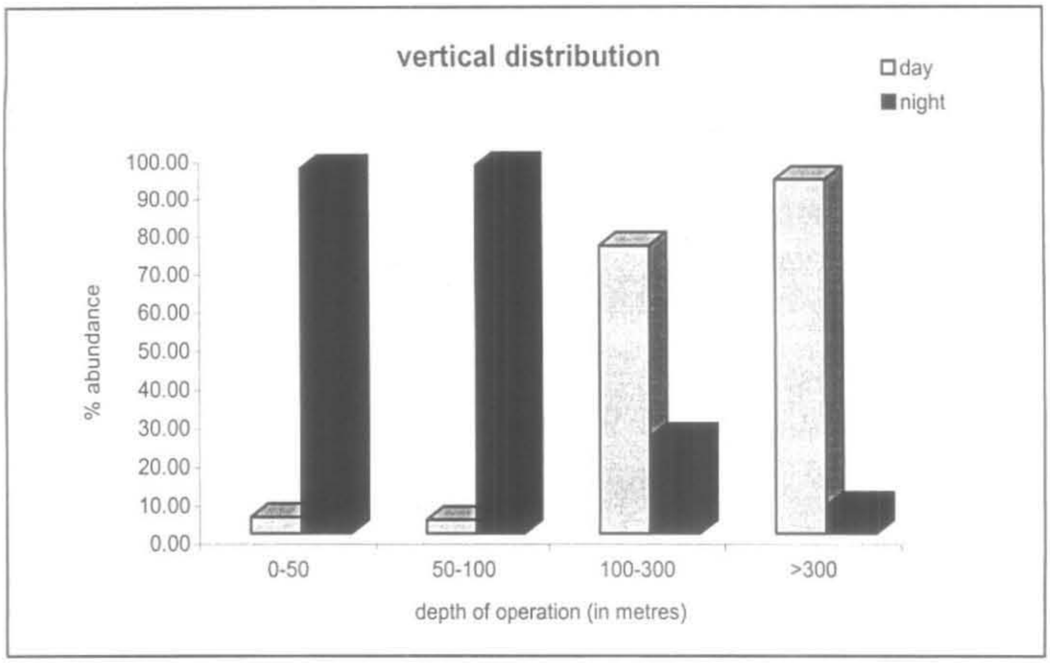


Fig.21. Congridae – Vertical distribution (day and night)

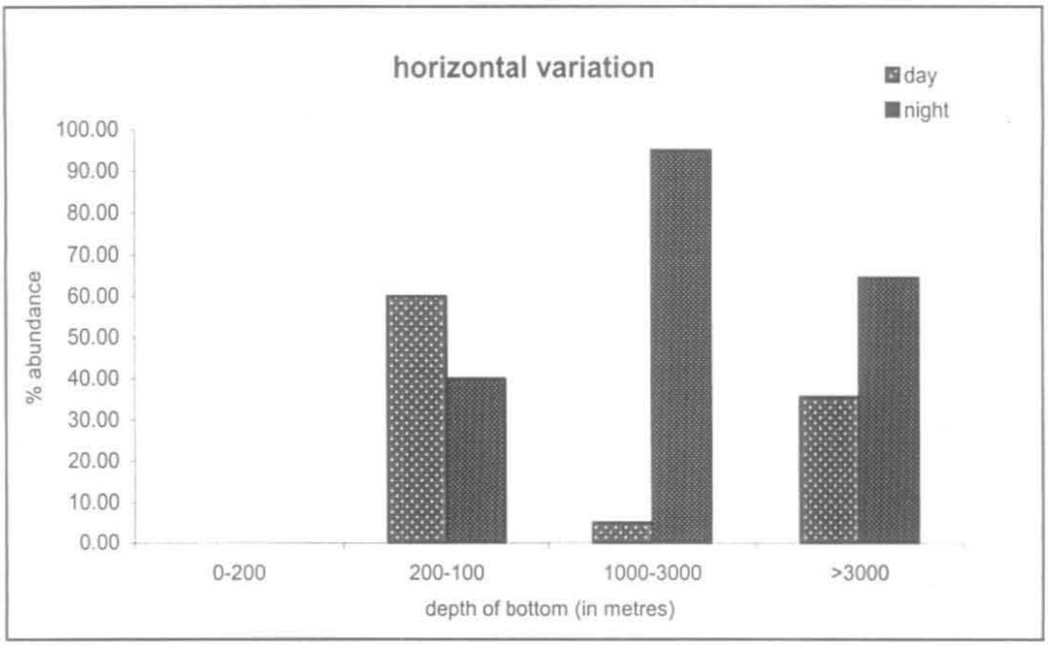


Fig.23. Congridae – Horizontal variation (day and night)

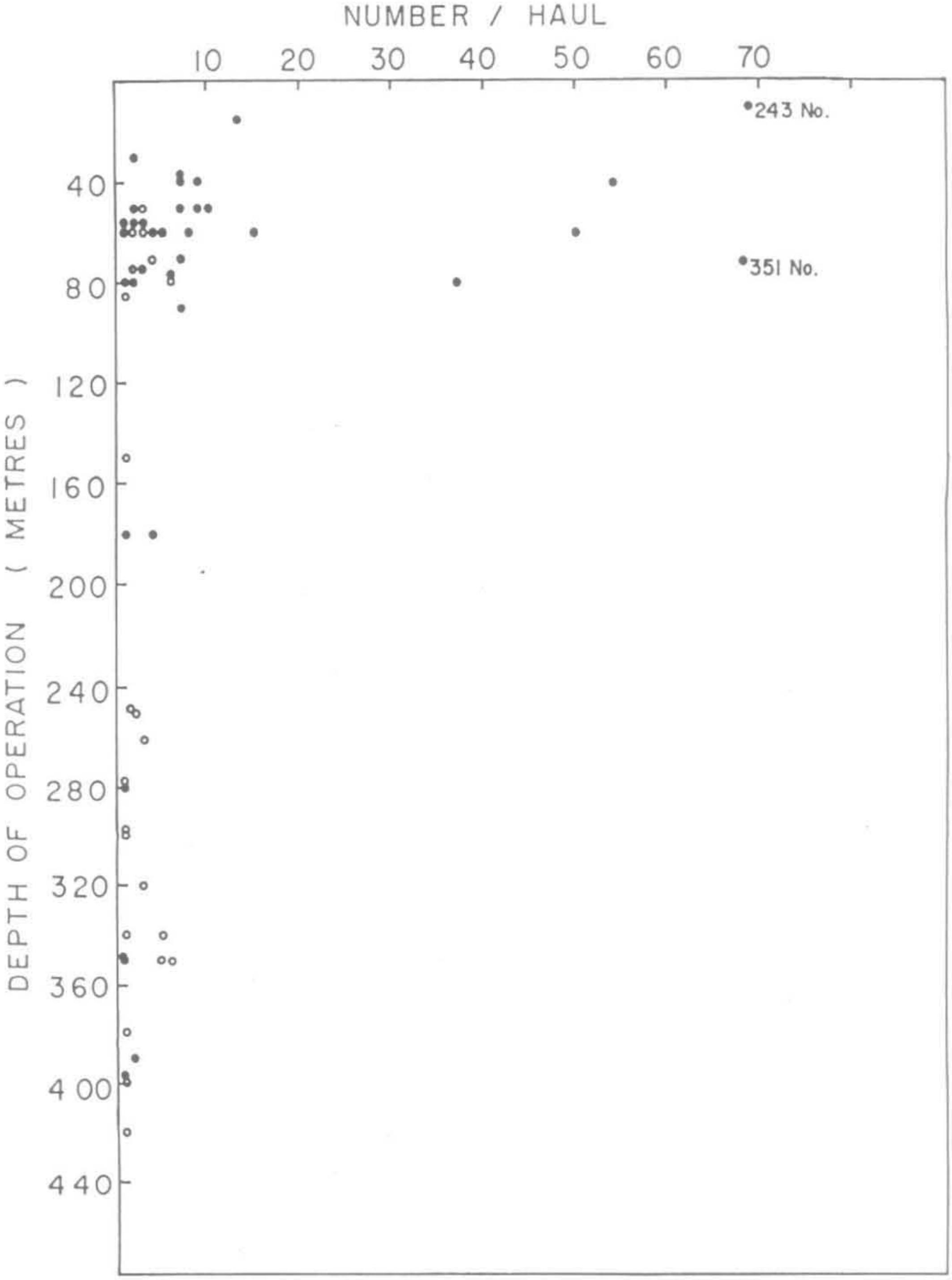


Fig: 22 Distribution (Day & Night) of Congridae (No. / haul) in the South West Coast of India

Family - Ophichthidae

Leptocephali of the family Ophichthidae represented as the second largest family in the IKMT collection, which formed 30% of the total leptocephali on the South west coast of India. The ophichthid leptocephali show a maximum aggregation off Mangalore in the 12° latitude. (Fig24)

The region wise abundance, as given in Table 10, clearly shows that the aggregation was more in the 12° latitude which contributing a major share of 78.08% of the total ophichthid catch. The percentage representation by all the other latitude were less than 10% of the total ophichthid catch in the south west coast of India.

Monthly abundance show a great degree of variation from a high of 73.66% to as low as 0.47%. The maximum abundance of ophichthid leptocephali was noticed in the month of July, contributing a share of 73.66% of the total ophichthid catch from the south west coast of India (Table 11). The study also states that the season wise abundance was more during monsoon (June-September). The catch contribution in other months was comparatively low.

Vertical abundance of the congrid leptocephali shows that the maximum contribution was from 50-100m, accounting to about 86.59% of the total, ophichthid leptocephali (Table 12). Representation in other depth ranges was very low in comparison (less than 10).

Studies revealed that the abundance of ophichthid leptocephali with respect to the depth of bottom was more in the depth zone of 1000-3000m contributing 85.49% of the total ophichthid catch. (Table 13). In the other depth zones the contribution was very low.

Abundance of the family Ophichthidae during a period of 24 hours shows that the catch was more during the early hours of the day between 04 00-08 00 hours, contributing to about 76.03% of the total.

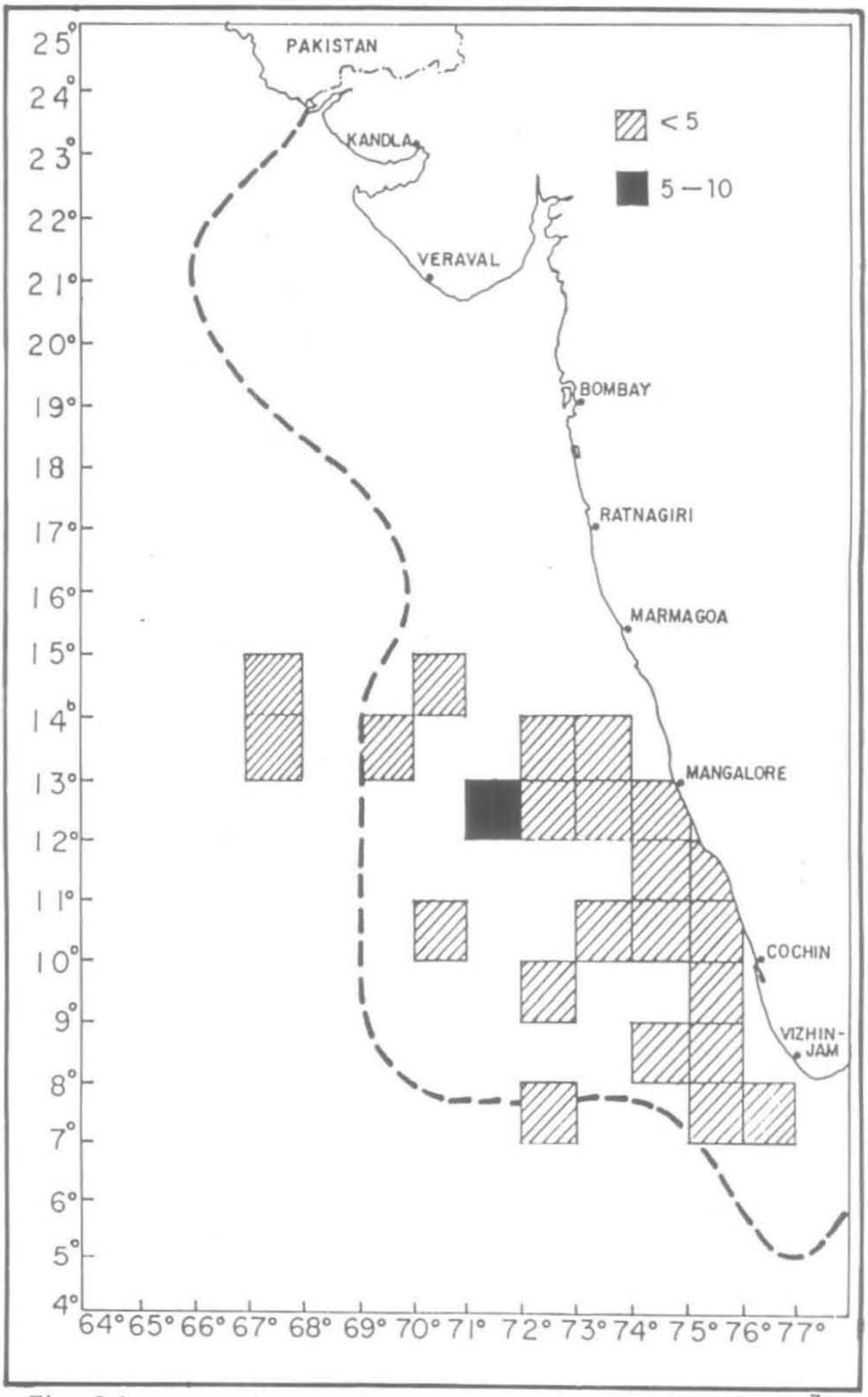


Fig: 24 Distribution and abundance of Ophichthidae (No/1000 m^3) in the South West coast of India

Table 10. Latitude wise abundance

Latitude	% Abundance
7	0.79
8	1.74
9	1.26
10	9.46
11	0.32
12	78.08
13	5.05
14	3.31

Table 11. Month wise abundance

Month	% Abundance
APRIL	2.68
MAY	4.89
JUNE	0.16
JULY	73.66
SEPTEMBER	0.47
OCTOBER	6.94
DECEMBER	11.20

Table 12. Vertical abundance

Depth of Operation (m)	% Abundance
0-50	5.52
50-100	86.59
100-300	0.95
>300	6.94

Table 13. Horizontal abundance

Depth of Bottom (m)	% Abundance
0 - 200	0.16
200 - 1000	6.94
1000 - 3000	85.49
>3000	7.41

Day-night abundance

a) Latitudinal variations

Studies on the diurnal abundance of ophichthid leptocephali revealed that the night catch was generally high through out, with a maximum representation at12° latitude (97.98%), followed by 10° and 13° latitudes with a contribution of 93.33% and 93.75%, respectively (Fig.25). The day catch was low in comparison, with the 7° latitude representing a major share of 60%.

b) Vertical distribution

Diurnal variation studies on different depths of operation revealed that 50 – 100m contributed maximum with a share of 97.81% (Fig.26). It was noted that the percentage representation of the night catch in the depth ranges of 0-50m (97.14%) and 50-100m (97.81%) were almost same with no predictable variation. The study also revealed that the aggregation of Ophichthidae was more within the depth range of 100m, especially during night with a maximum number of 452 numbers in one instance. The leptocephali were available to a maximum depth of 750m (Fig.27). The percentage contribution of day catch was more on 100-300m depth range (83.33%).

c) Horizontal distribution

The studies revealed that the maximum representation in the night catch was in the depth zone of 1000 – 3000m (96.86%), followed by 200-1000m with a share of 86.36%. The percentage representation of day catch was maximum in the depth zone above 3000m (44.68%) (Fig28).

d) Monthly abundance

It was noted that the month of July contributed maximum of the night catch with a share of 98.07% and October for day (43.18%) (Fig.29). The studies also show the season wise abundance of the ophichthid leptocephali during the monsoon.

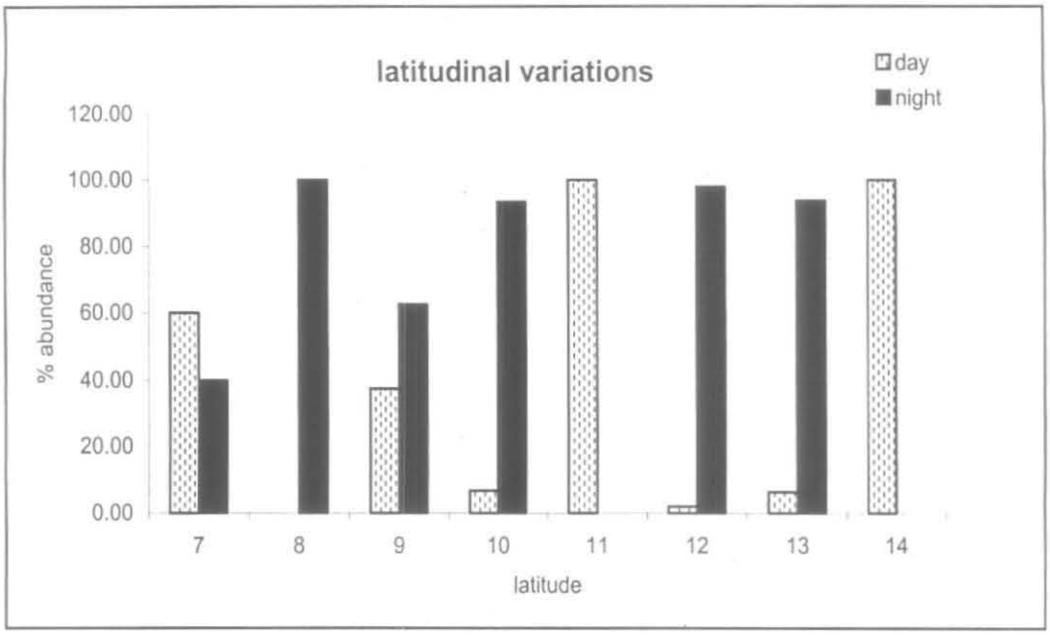


Fig.25. Ophichthidae – Latitudinal variations (day and night)

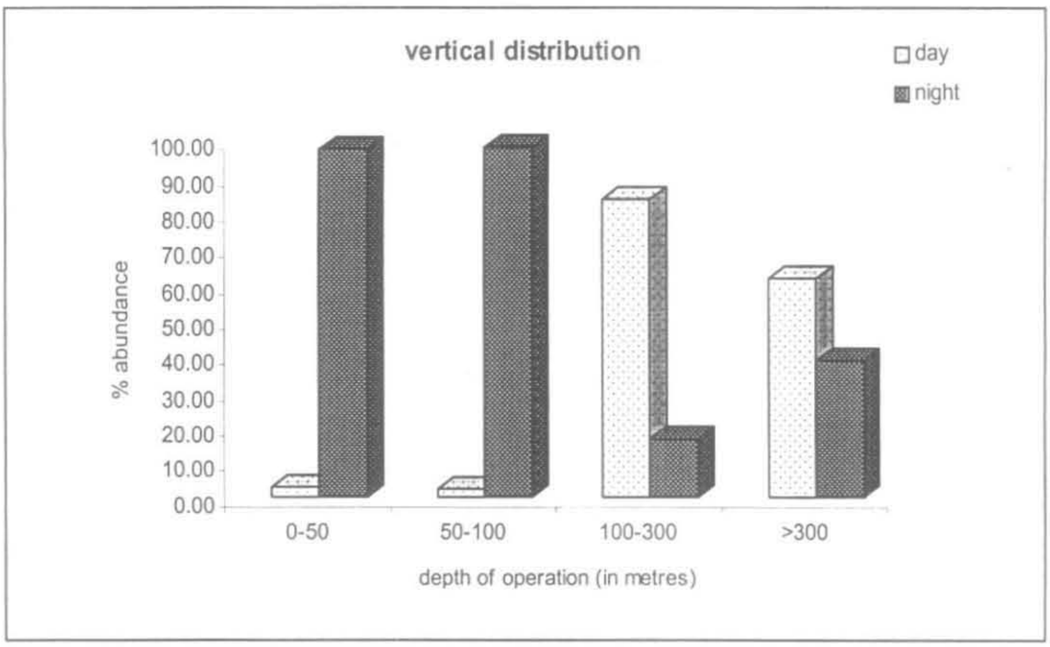


Fig.26.Ophichthidae – Vertical distribution (day and night)

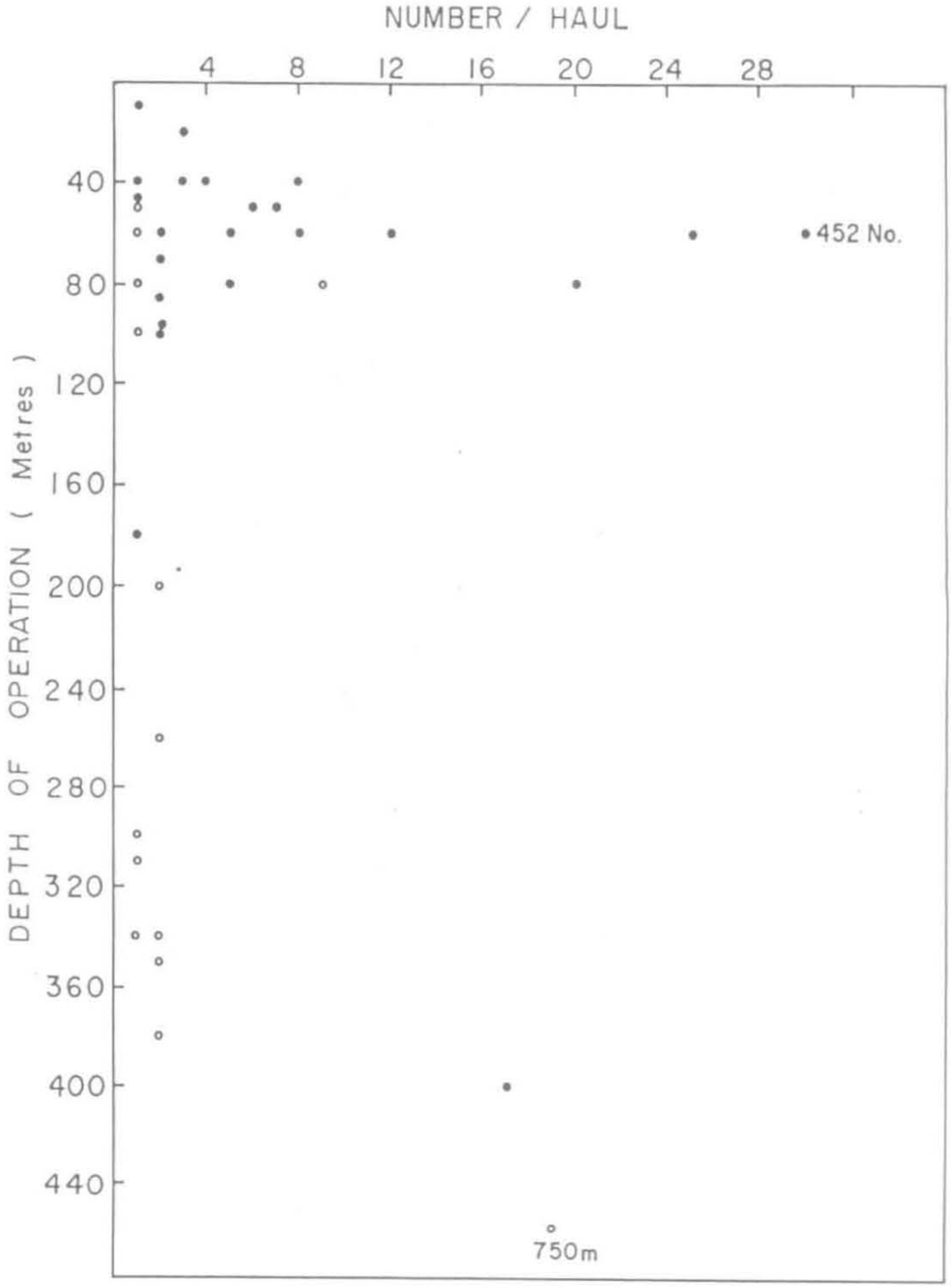


Fig: 27 Distribution (Day & Night) of Ophichthidae (No./haul)
in the South West Coast of India

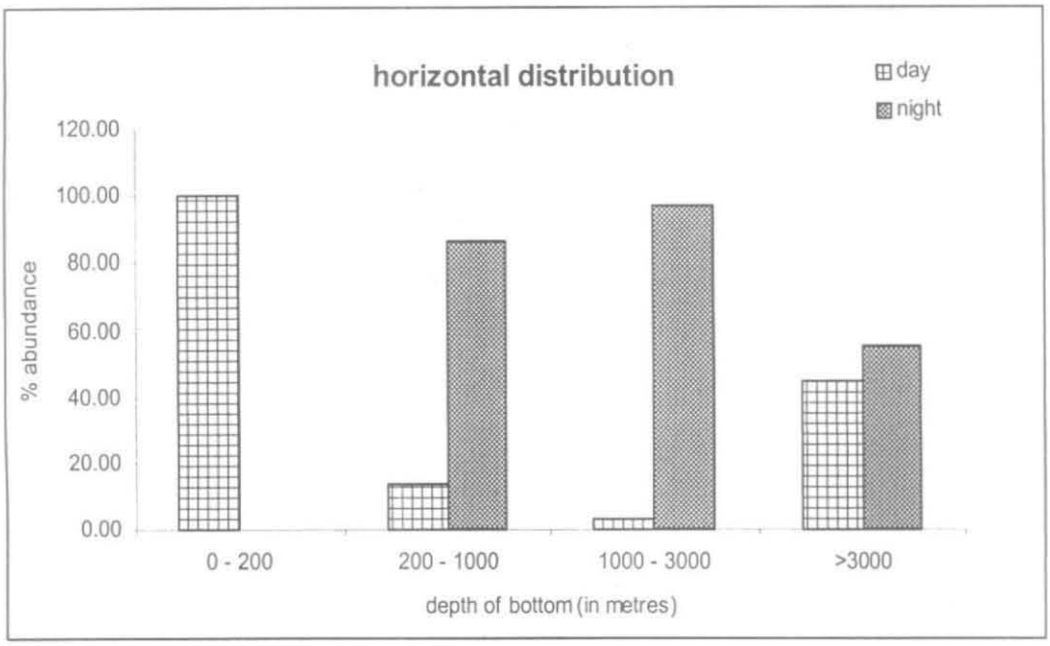


Fig.28. Ophichthidae – Horizontal distribution (day and night)

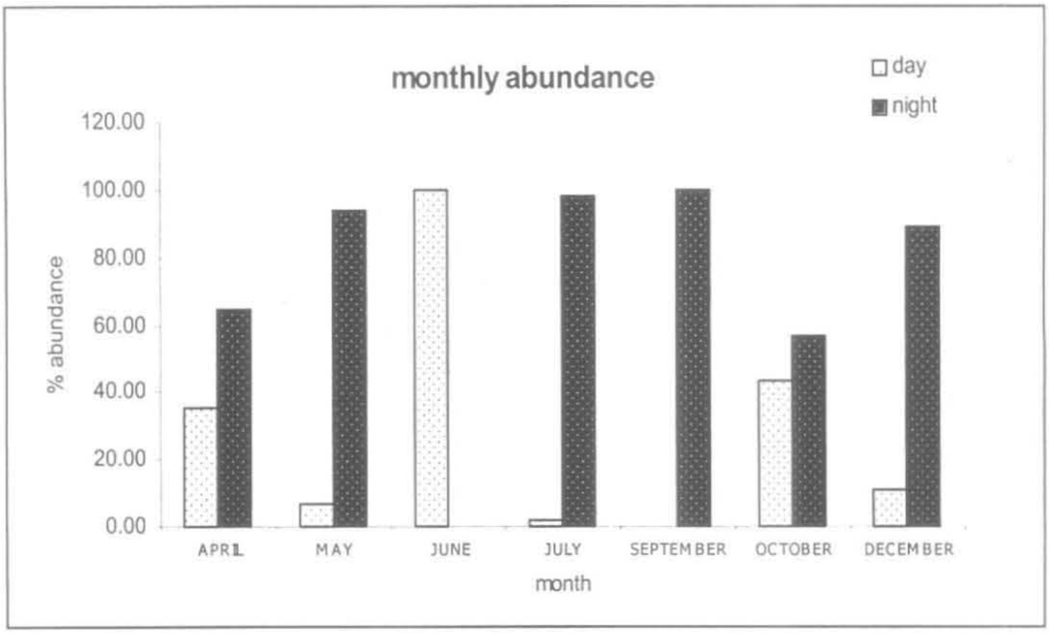


Fig.29. Ophichthidae – Monthly abundance (day and night)

Family - Muraenidae

Though the third largest family in the IKMT collection the representation of Muraenid leptocephali was very less in comparison with Congridae and Ophichthidae, which formed only 2.65% of the total south west coast leptocephali. Even though the numerical abundance was less, the leptocephali were evenly distributed with no dense pocket of abundance. In general, the distribution and abundance was slightly prominent in the area between 8° and 11° latitudes. (Fig.30)

Latitude wise abundance shows not much variation but with a slightly high abundance in the 10° latitude constituting to about 25.93% of the total muraenid catch (Table14). In other latitudes the percentage representation varied from a low of 1.85% to 16.67%.

Vertical abundance of the muraenid leptocephali was high in the depth range of 50-100m, accounting to about 61.11% of the total. The contribution in other depth ranges was low in comparison (less than 20%). The lowest percentage abundance was from the depth above 300m (3.70%) (Table 15)

The muraenid leptocephali were totally absent in the 0-200m depth (bottom) zone. In the other depth zones, 1000-3000m region contributed the highest with a 50% representation of the total muraenid leptocephali, followed by 200-1000m range (42.59%) (Table 16). The percentage contribution of the region above 3000m was very poor, accounting to only 7.41%.

Sample analyses revealed that the monthly abundance of the muraenid leptocephali were more in December which contributing to about 53.70% of the total. The month of May contributed to about 18.52%, where as in rest of the months the percentage contribution was less than 10. (Table 17)

Diurnal variation shows a maximum abundance during the early hours of the day between 04 00 – 08 00 hours, contributing 33.33% of the total muraenid leptocephali in the southwest coast of India.

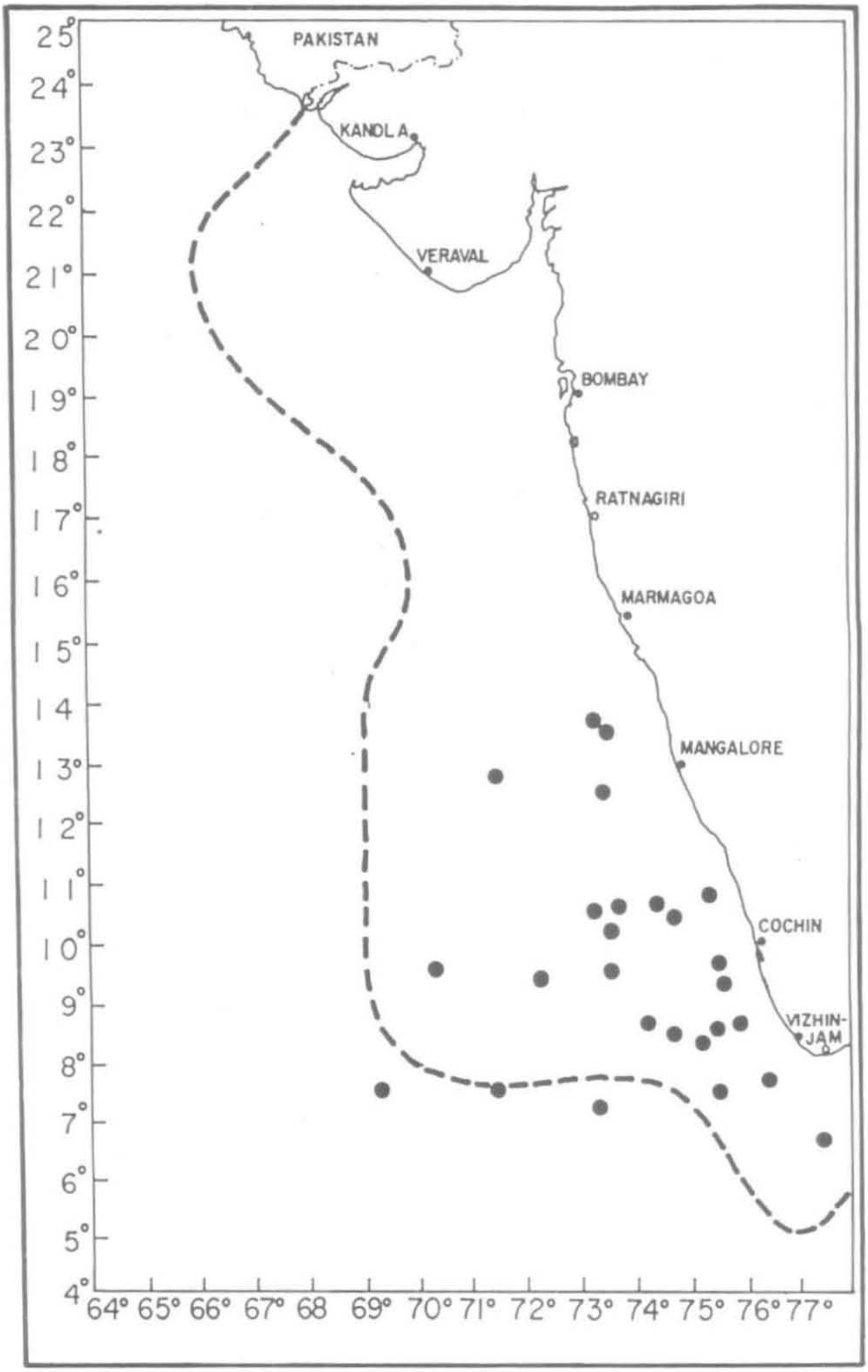


Fig: 30 Distribution of Muraenidae in the South West coat of India

Table 14. Latitudinal abundance

Latitude	% Abundance
6	1.85
7	11.11
8	12.96
9	16.67
10	25.93
12	14.81
13	16.67

Table 15. Vertical abundance

Depth of Operation (m)	% Abundance
0 - 50	16.67
50 - 100	61.11
100 - 300	18.52
>300	3.70

Table 16. Horizontal abundance

Depth of Bottom (m)	% Abundance
0 - 200	0.00
200 - 1000	42.59
1000 - 3000	50.00
>3000	7.41

Table 17. Month wise abundance

Month	% Abundance
APRIL	5.56
MAY	18.52
JUNE	3.70
JULY	1.85
SEPTEMBER	7.41
OCTOBER	9.26
DECEMBER	53.70

Day-night variation

a) Latitudinal abundance

The general abundance of the muraenid leptocephali was low, though it formed as the third largest family in the IKMT collection. Latitude wise day-night abundance shows that the percentage contribution to the night catch was high in the 10° latitude (85.71%) and a low contribution of 11.11% in the 9° latitude. The daytime contribution was high in the 9° latitude with a share of 88.89%. (Fig.31)

b) Vertical abundance

The operational depth wise studies shows that during the muraenid leptocephali concentrated more in the 50-100m depth range with a percentage representation of 87.88 (Fig 32). The daytime catch was maximum in the 0-50m depth range (33.33%). The studies further revealed that generally the muraenid leptocephali aggregated with in the depth range of 100m, especially in the night and also making its presence up to a depth of 420m (Fig.33).

c) Horizontal abundance

There was a total absence of muraenid leptocephali in the 0-200m depth zone. Studies also revealed that the percentage contribution to the night catch was high in the depth zone of 1000-3000m (77.78%), where as for the daytime, it was the depth zone above 3000m with 75% (Fig.34).

d) Monthly abundance

Monthly abundance of the muraenid leptocephali during night revealed that the percentage representation was high during the month of December (79.31%), and a low of 33.3% in April. The daytime catch was high in the month of April (66.67%). (Fig. 35)

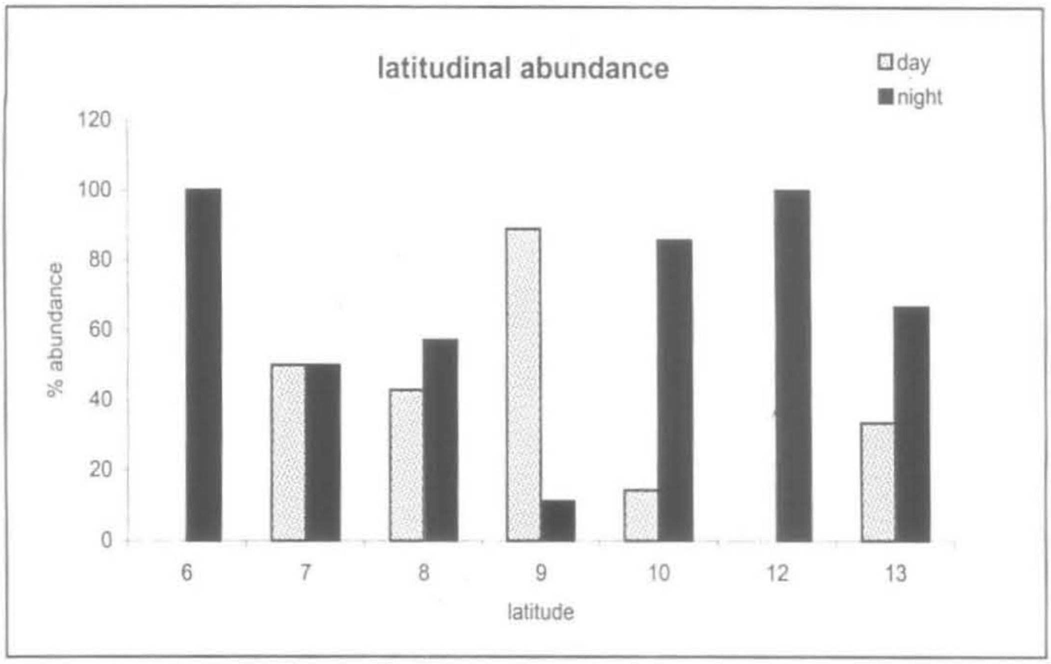


Fig.31. Muraenidae – Latitudinal abundance (day and night)

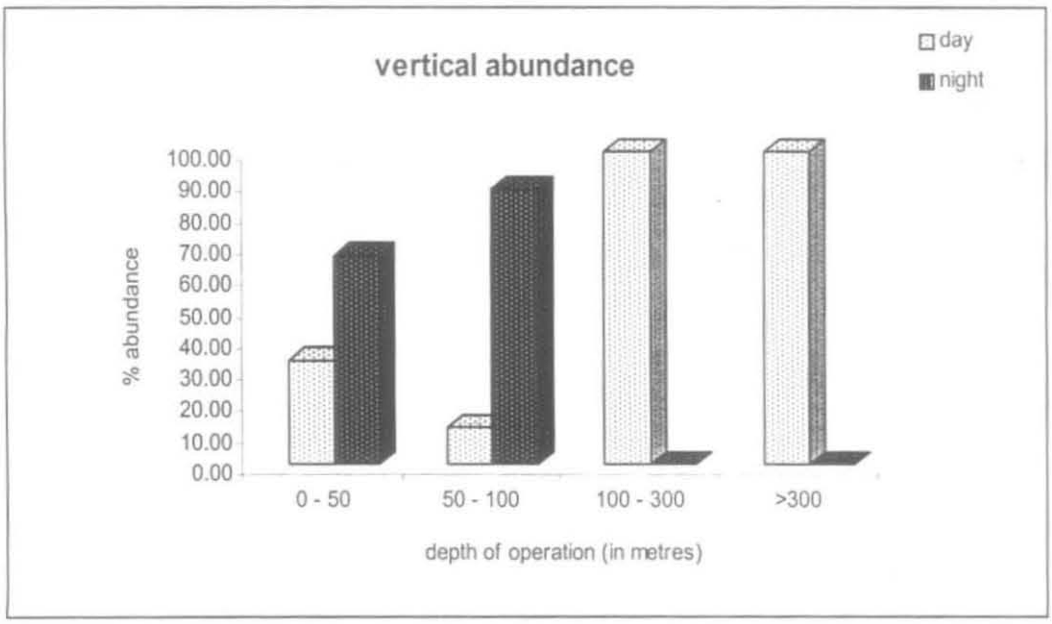


Fig.32. Muraenidae-vertical abundance (day and night)

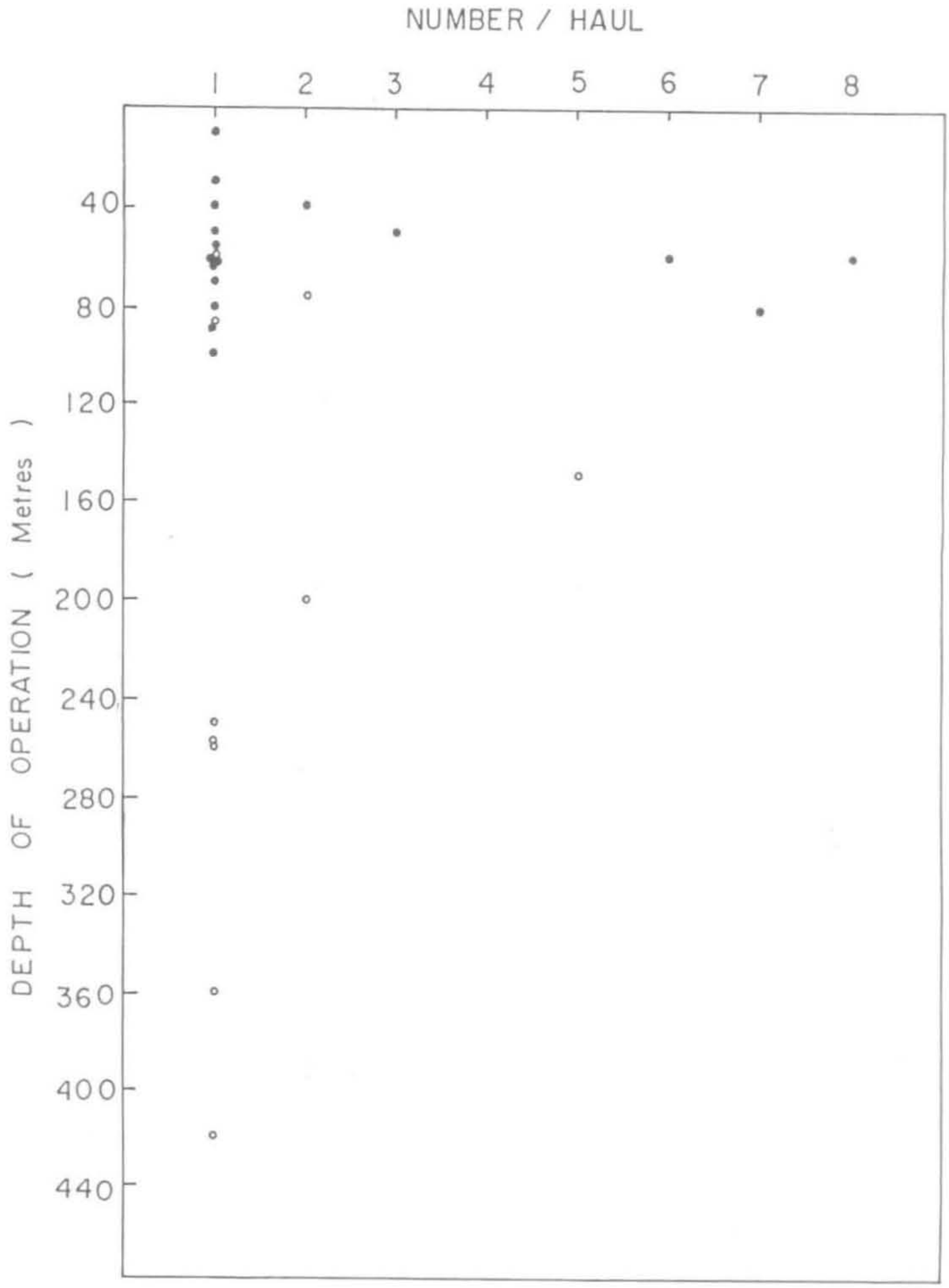


Fig: 33 Distribution (Day & Night) of Muraenidae (No. / haul)
in the South West Coast of India

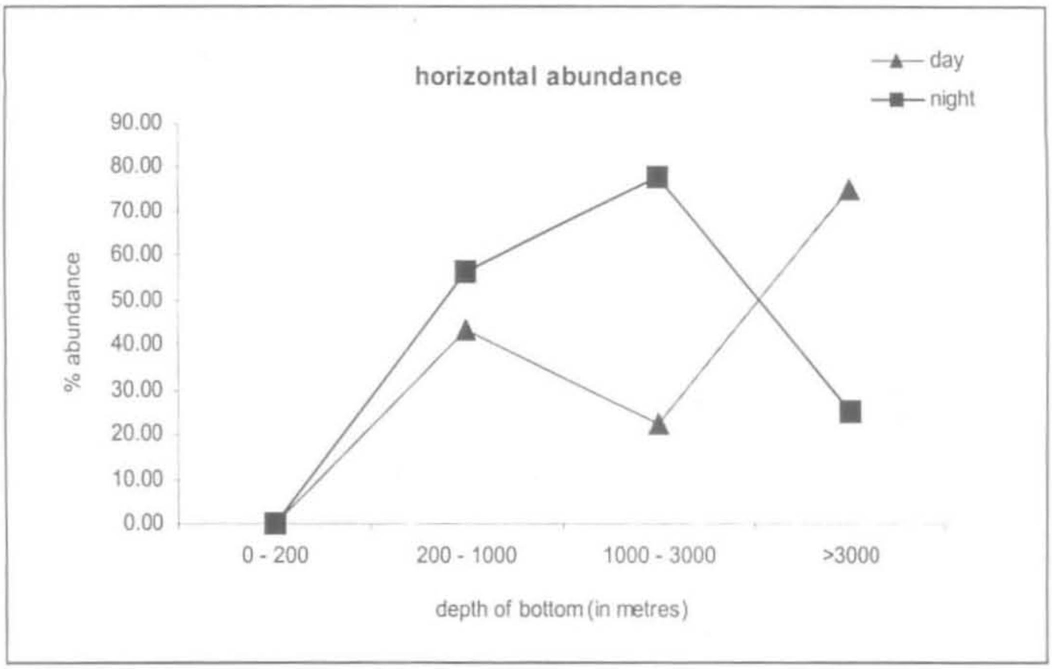


Fig.34. Muraenidae-horizontal abundance (day and night)

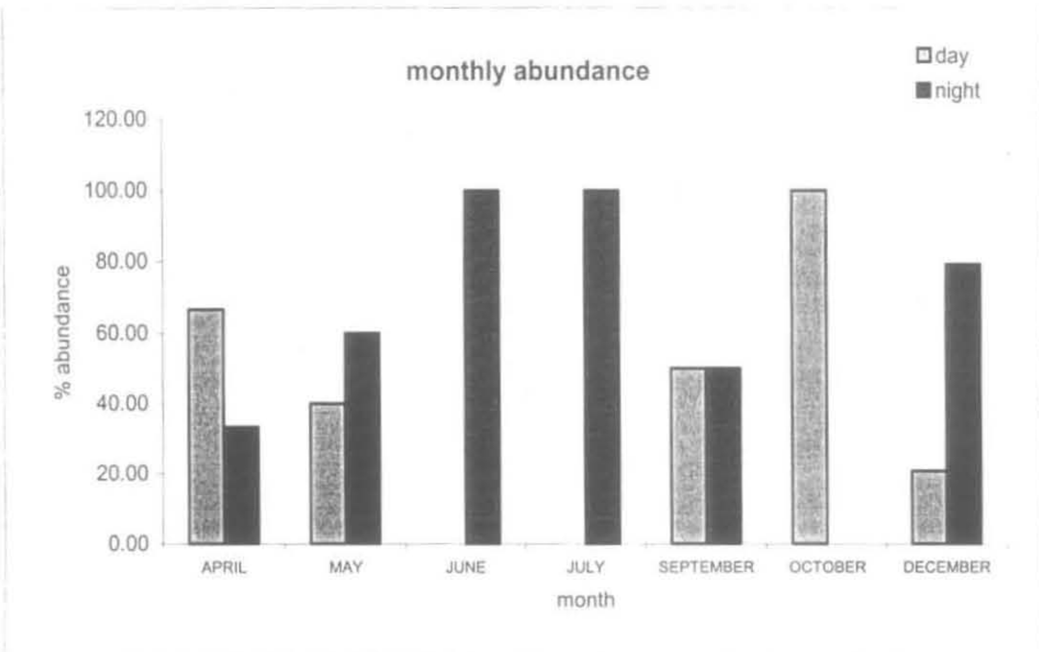


Fig.35. Muraenidae-monthly abundance (day and night)

Family – Nemichthyidae and Synaphobranchidae

The leptocephali of two families viz. Nemichthyidae and Synaphobranchidae formed only a negligible percentage (1.5% and 0.83%, respectively) in the southwest coast of India. They were present only in 12 and11 stations respectively, in small numbers. The distribution of the two families is given in Fig 36.

Latitudinal distribution

The leptocephali of both the families show a scattered distribution along the different latitudes. Maximum number per haul for Nemichthyidae was seven and Synaphobranchidae four in the 13° and 10° latitudes, respectively. The latitude wise distributions of the two families are given in Table18 and 19.

Vertical distribution

Leptocephali of both the families were present to a maximum depth of 380m (Nemichthyidae) and 400m (Synaphobranchidae). (Fig.37 and 38;Table 20 and 21). Nemichthyid leptocephali were more abundant in the depth range of 370m (7 numbers) where as that of Synaphobranchidae in the 120m depth range (4 numbers).

Horizontal distribution

The nemichthyid and synaphobranchid leptocephali were found to aggregate in deeper waters, with a maximum depth of abundance of 4633m and a minimum of 300m and 531m for Nemichthyidae and Synaphobranchidae, respectively. (Table 22 and 23)

Due to the scarcity of samples, the analyses of data for other parameters were not possible.

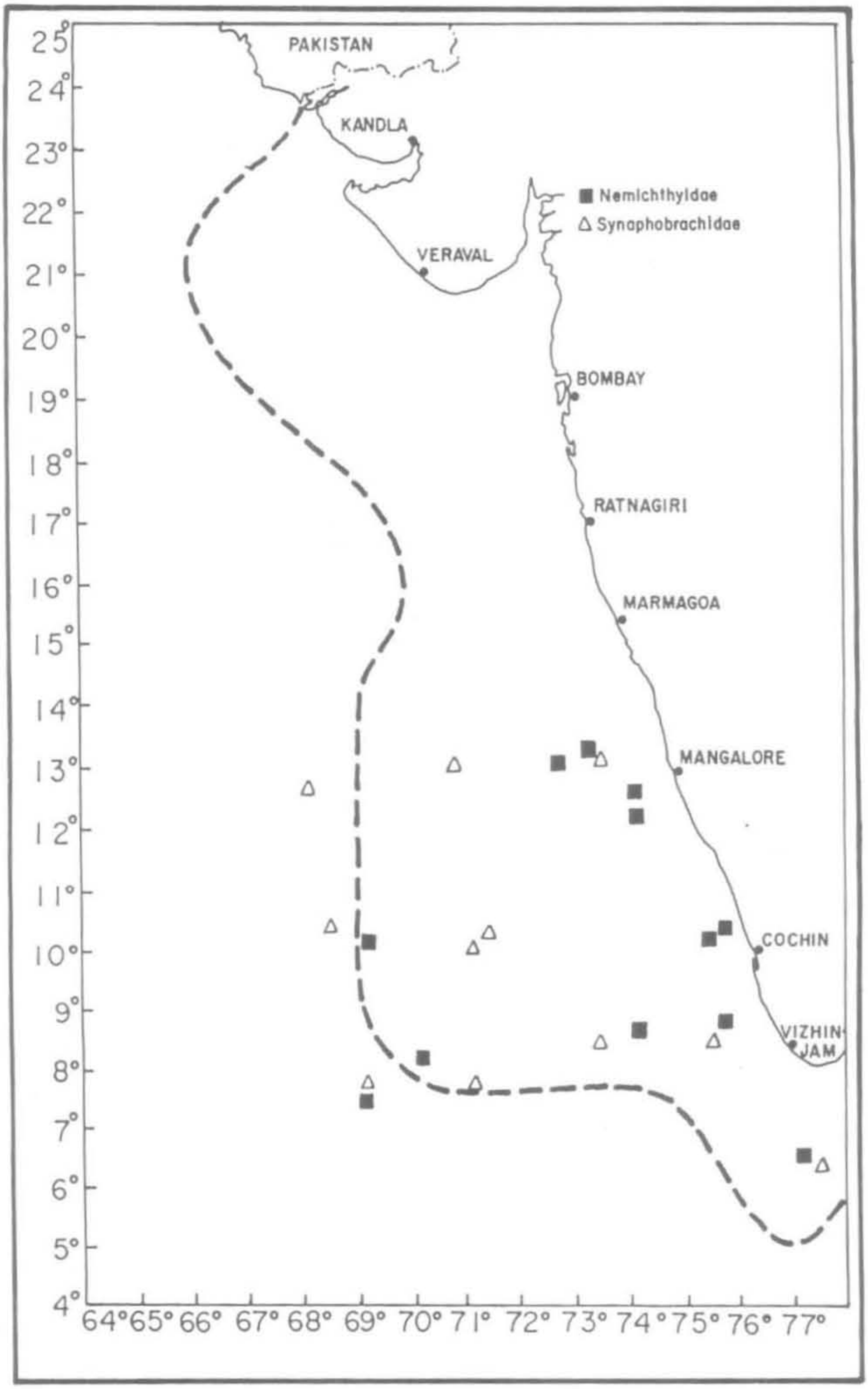


Fig. 36: Distribution of Nemichthyidae and Synaphobranchidae in the South-West coast of India

Table18. Nemichthyidae

Latitude (°N)	Longitude (°E)	No./haul
6° 38	77° 31	2
7° 59	69° 02	2
8° 40	75° 36	1
8° 00	74° 04	1
8° 00	70° 02	1
10° 00	69° 00	1
10° 16	75° 29	6
10° 21	75° 34	3
12° 34	74° 06	3
12° 28	74° 09	1
13° 01	72° 57	3
13° 09	73° 40	7

Table 19. Synaphobranchidae

Latitude (°N)	Longitude (°E)	No./haul
6° 38	77° 31	1
7° 59	69° 02	1
7° 52	71° 12	1
8° 30	75° 30	2
8° 29	73° 32	1
10° 25	71° 31	1
10° 00	71° 00	1
10° 31	68° 32	4
12° 54	68° 04	1
13° 00	70° 57	2
13° 09	73° 40	2

Table 20. Nemichthyidae

Depth of Operation (m)	No./haul
30 - 40	2
40 - 50	1
50	6
60	1
90	1
100	3
180	1
250 - 300	2
300	3
340	3
370	7
380	1

Table 21. Synaphobranchidae

Depth of Operation (m)	No./haul
60 - 80	1
75	2
120	4
250	1
250 - 300	1
280	1
320	2
350	1
370	2
390 - 400	1
400	1

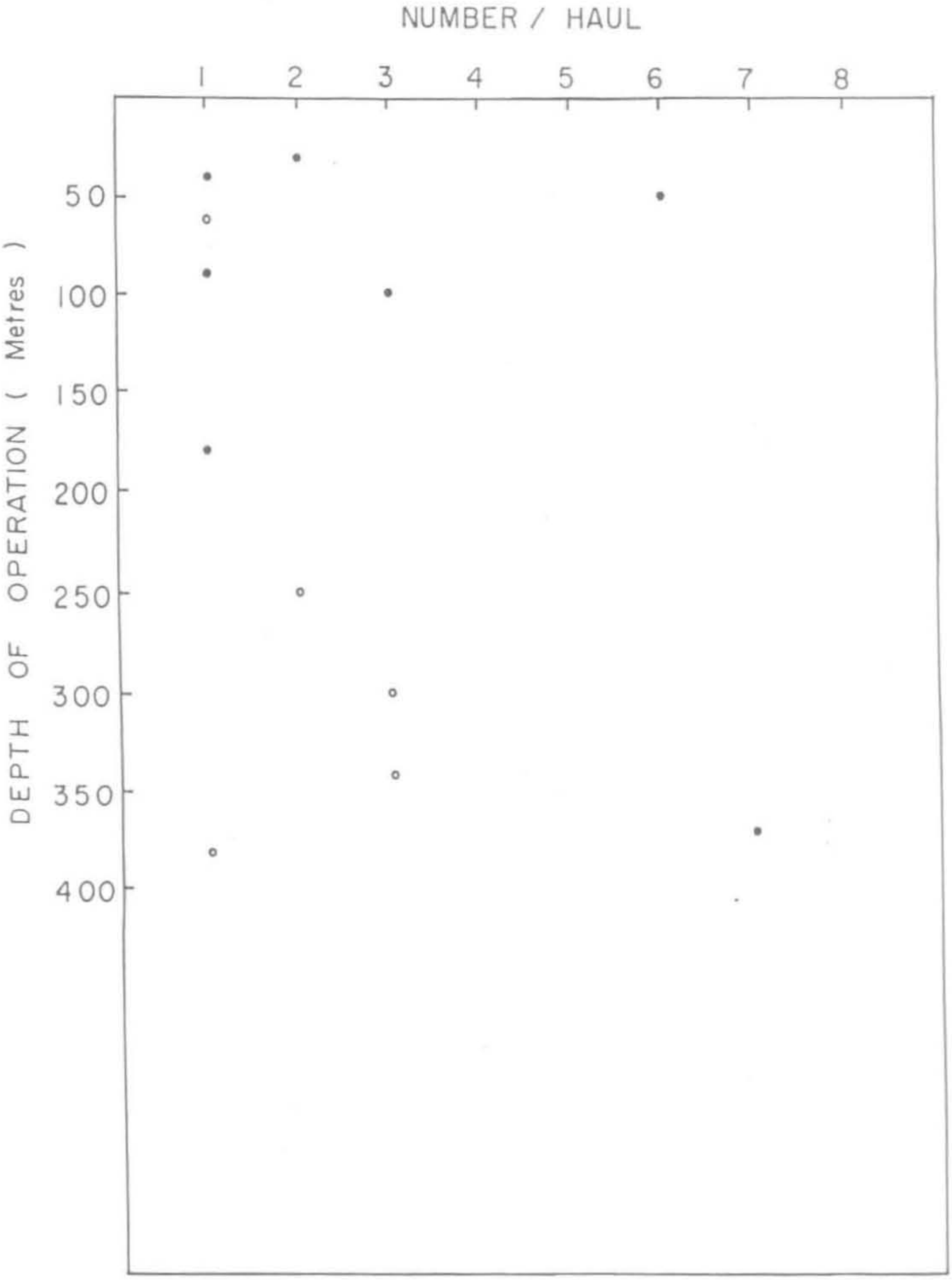


Fig: 37 Distribution (Day & Night) of Nemichthyidae (No./haul) in the South West Coast of India

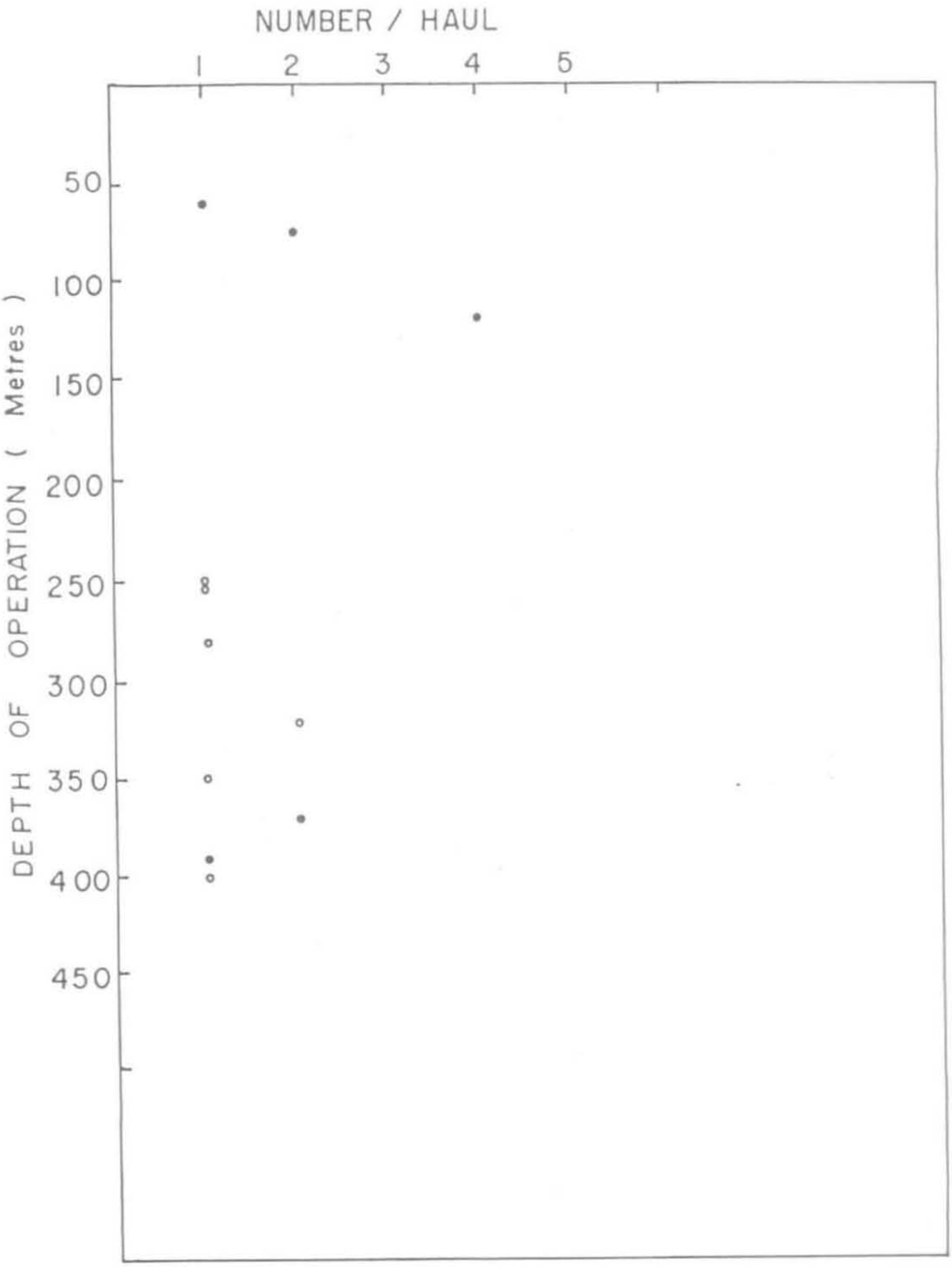


Fig : 38 Distribution (day & night) of Synaphobranchidae (No./haul) in the South West Coast of India

Table 22. Nemichthyidae

Depth of Bottom (m)	No./haul
300	1
395	1
500	3
531	7
792	3
1089	6
1937	3
2415	2
2770	1
4181	1
4514	1
4633	2

Table 23. Synaphobranchidae

Depth of Bottom (m)	No./haul
531	2
1409	2
2039	1
2310	1
2405	2
2415	1
3351.3	1
3646	1
4186	1
4452	4
4633	1

Biomass estimation of Leptocephali

West Coast

To understand the resource potential, the estimation of total biomass was carried out. The biomass was calculated in tones for every 1° square. The study revealed that leptocephali had a fairly good abundance along the west coast of India. It was present on all depth ranges – vertically (0-50m, 50-100m, 100-300m, >300m) or horizontally (0-200m, 200-1000m, 1000-3000m, >3000m) and on every latitude from 6°N to 21°N. The total biomass on the west coast was 76227.87t with an average of 515.05t (148 stations). Maximum biomass was recorded in the 19° latitude, off Bombay (6481.88t). North west coast accounted for the major share (54817.65t) of total leptocephali biomass, which formed 71%. The major stations where the leptocephali biomass was more than 1000t are given in Table 24.

Geographical variation in Biomass

The abundance of leptocephali (in tones) was more or less even through out the west coast with a single high density pocket (>3000t) in the northwest region (19°N – 68°E). The least density areas (<100t) were more concentrated towards the south, particularly in the near shore waters of Mangalore. In comparison with the north west coast there was only one dense area of abundance (1000-3000t) in the south west coast, off Mangalore. In general, the abundance was more prominent in the north west coast. (Fig.39)

Latitudinal abundance

The leptocephali were found abundant in the area above 15° latitude with a dense area of abundance (>3000t) in the 19° latitude (off Bombay). Latitude wise average biomass value ranged from a high of 1973.14t (19° latitude) to a low of 25.82t in the 11° latitude (Fig.40).

Table24. Major areas with higher biomass (>1000t)

Station No.	Area of operation	Latitude	Longitude	Time (Hrs)		DSL thickness (m)	Depth of operation (m)	Depth of bottom (m)	No. of Leptocephali	Biomass 1^0Square (in Tones)
				From	To					
17	SW	9^0 29	72^0 30	20 50	21 40	10	70	1810	373	1660.05
101	NW	18^0 07	64^0 35	20 00	20 30	30	30-145	1603	279	3725.84
103	NW	18^0 23	70^0 10	11 35	12 05	40	40-80	1345	140	2493.79
104	NW	18^0 27	70^0 30	17 10	17 40	60	40-80	332	184	4913.36
116	SW	12^0 30	71^0 29	05 25	05 55	10	60-70	1584	509	2266.18
138	NW	15^0 19	72^0 52	21 44	22 15	20	15-35	229	140	1246.9
155	NW	18^0 35	70^0 17	22 30	23 00	50	35-45	764	52	1162.78
158	NW	19^0 33	69^0 20	23 35	00 05	25	35	1182	215	2393.6
495	NW	16^0 59	68^0 00	17 30	18 00	110	190	3539	31	1523.98
496	NW	17^0 00	69^0 00	04 45	05 15	35	65	2572	72	1121.34
497	NW	17^0 00	70^0 00	16 10	16 40	40	320	3476	189	3364.64
499	NW	16^0 59	71^0 51	17 25	17 55	10	185	227	242	1077.43
503	NW	18^0 59	70^0 00	02 30	03 00	25	50	254	331	3686.26
504	NW	19^0 00	68^0 58	11 40	12 10	80	320	2809	182	6481.88
508	NW	21^0 00	66^0 59	22 00	22 30	120	35	2382	20	1068.77
697	SW	8^0 00	75^0 00	23 00	00 00	100	40	2749	26	1162.78
704	SW	10^0 00	71^0 00	17 30	18 00	250	280	3646	20	2226.6
773 d	SW	12^0 57	73^0 53	03 50	04 20	60	80	419	39	1039.08
795	NW	20^0 55	66^0 55	20 30	21 00	80	40	2440	31	1108.35
794	NW	21^0 00	67^0 58	17 10	17 40	160	280-300	2665	17	1207.31
786	NW	16^0 58	69^0 59	11 35	12 05	100	340-400	3485	30	1335.96

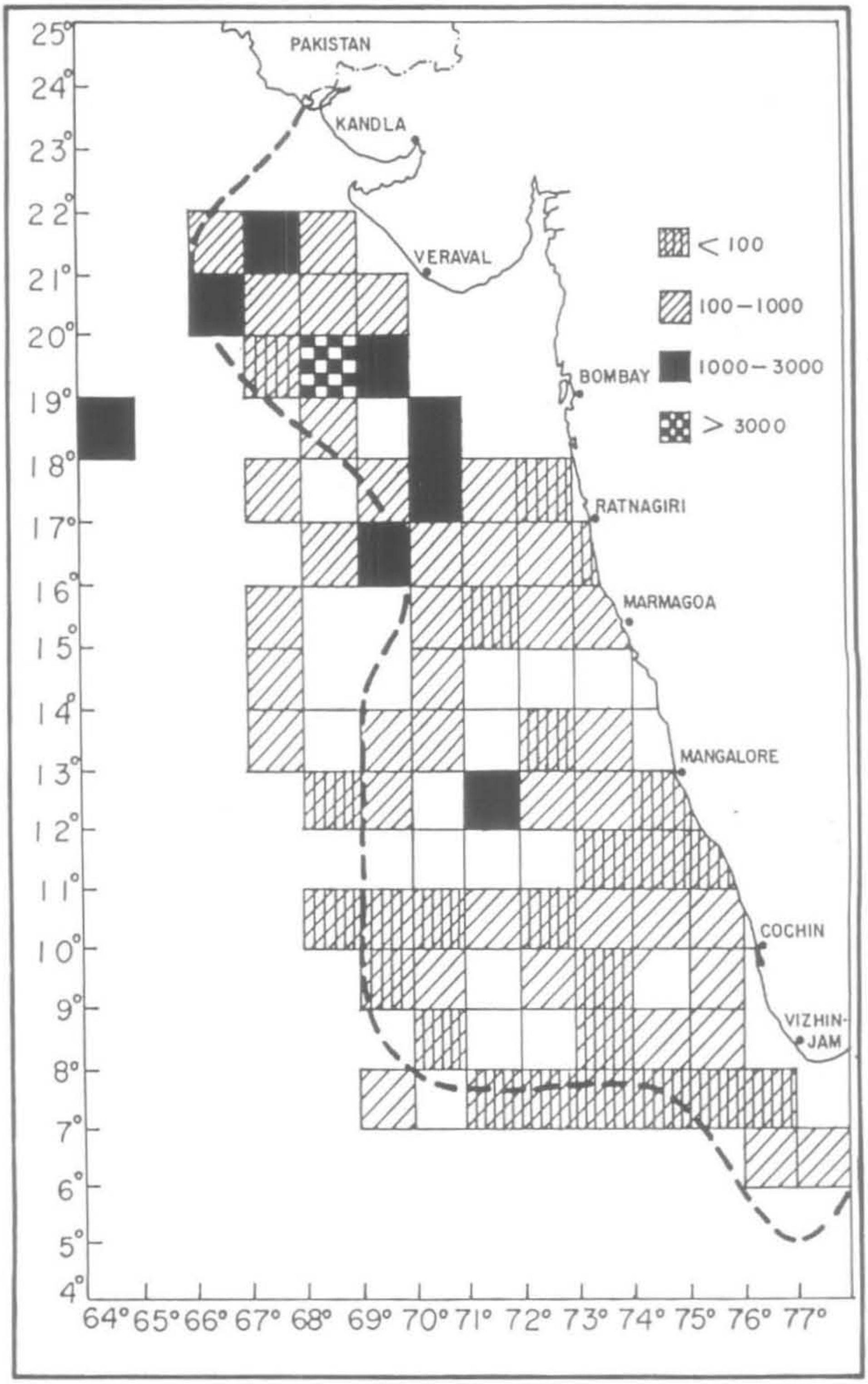


Fig. 39 Leptocephali – Total Biomass (Tonnes)
in the West- coast of India

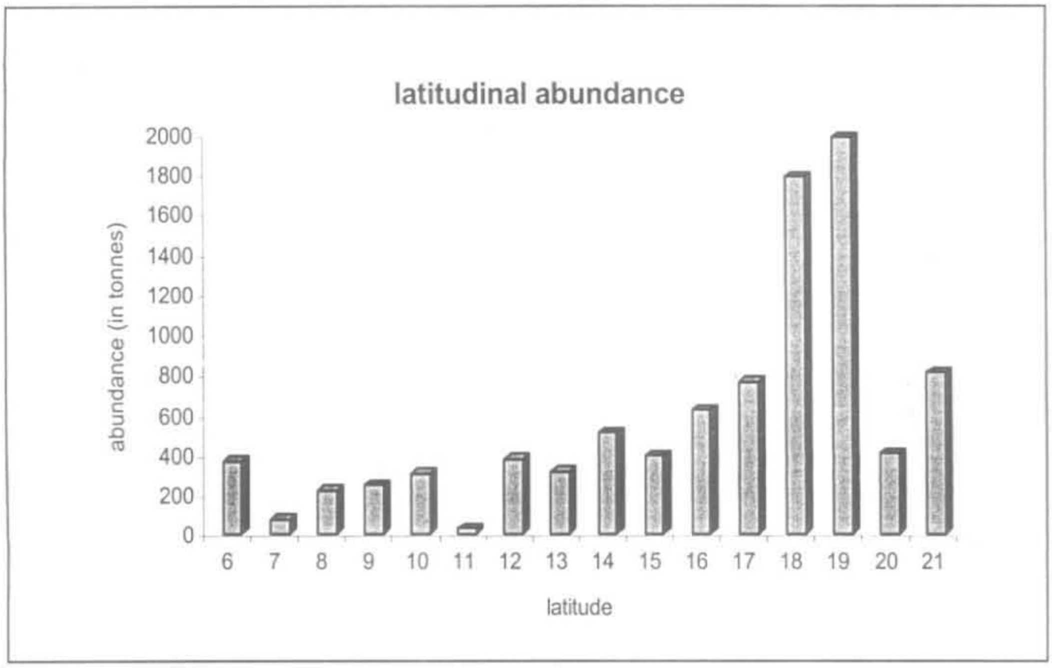


Fig.40. Latitudinal abundance of Leptocephali

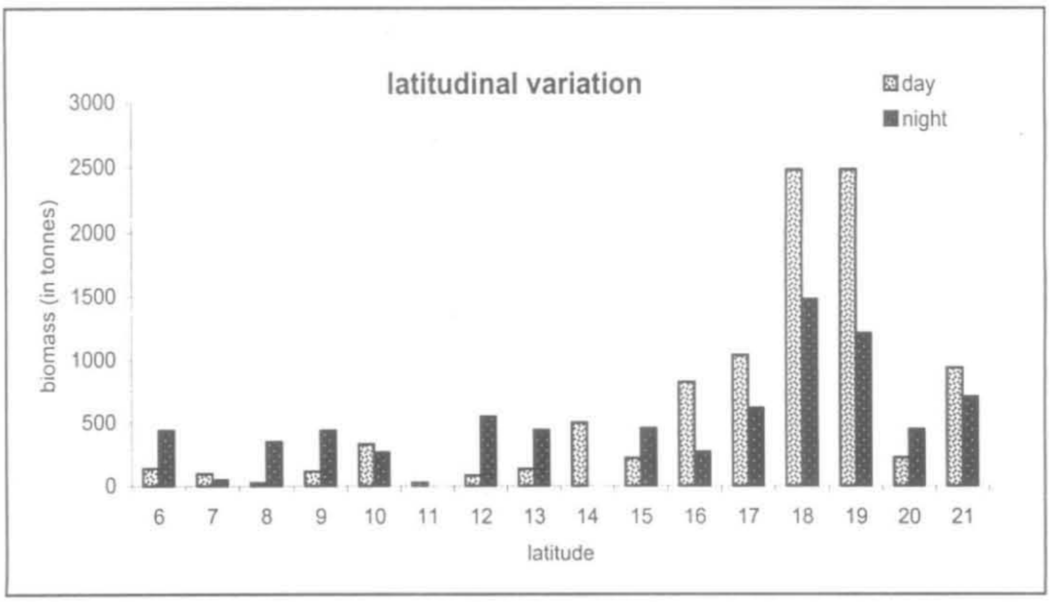


Fig.41. Latitudinal variation (day and night) in biomass of leptocephali

Day - night variations

The analyses revealed that the night biomass was more in comparison, constituting to about 55.96% of the total biomass where as, the day was 44.04%.

a) Latitudinal variation

The latitude wise estimated biomass (average) during day and night is presented in Fig.41. It shows a variation of 21.96t to a maximum of 2481.01t. The night biomass was high in the 18° latitude (1480.33t) where as that of day at 19° latitude 2481.01t.

b) Monthly variations

Monthly variations in the biomass showed a maximum in the month of March with 1166.49t during night and 2563.81t during day. In general, the biomass (average) varied from a low of 69.27t to maximum of 1726.7t through the seasons. (Fig.42)

c) Vertical abundance

Analyses revealed that the biomass (average) was maximum in the depth range of 0-50m during day (849.32t) and night (649.93t) and also in total (726.44t) (Fig.43). The minimum nighttime biomass was recorded in the 100-300m range (113.98t) where as that of the day (56.85t) in the 50-100m depth range.

d) Horizontal abundance

Bottom depth wise studies on the biomass revealed that the over all biomass was maximum in the depth zone above 3000m where as the minimum was at 0-200m depth zone. Diurnal variations show that nighttime biomass was maximum in the 1000-3000m depth zone (600.19t) and that of day (767.68t) in the zone above 3000m. (Fig.44)

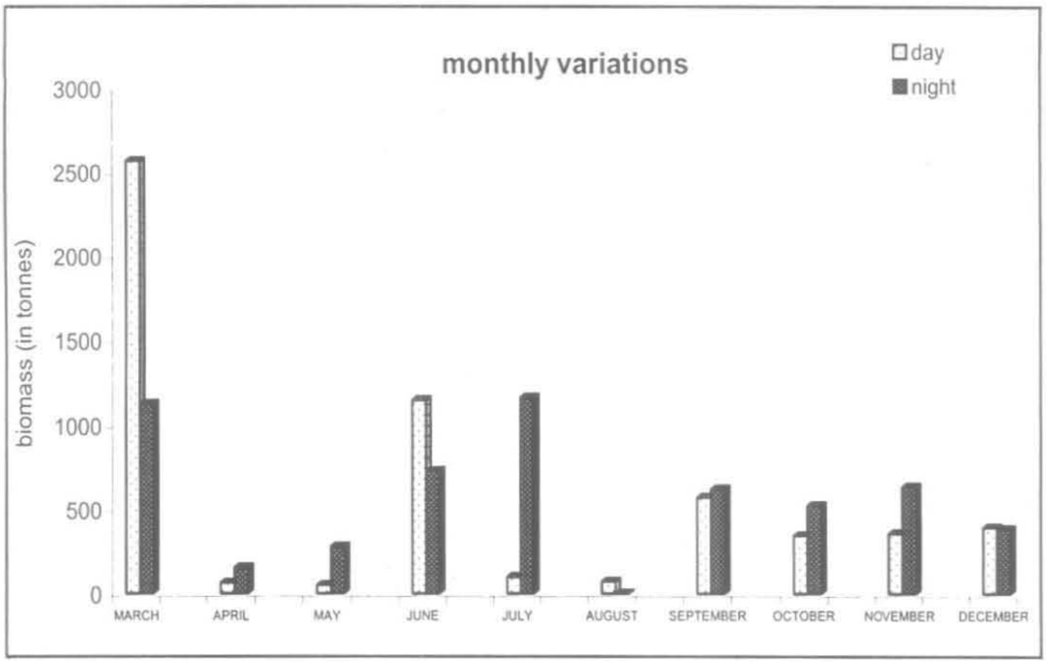


Fig.42. Monthly variations in biomass (day and night)

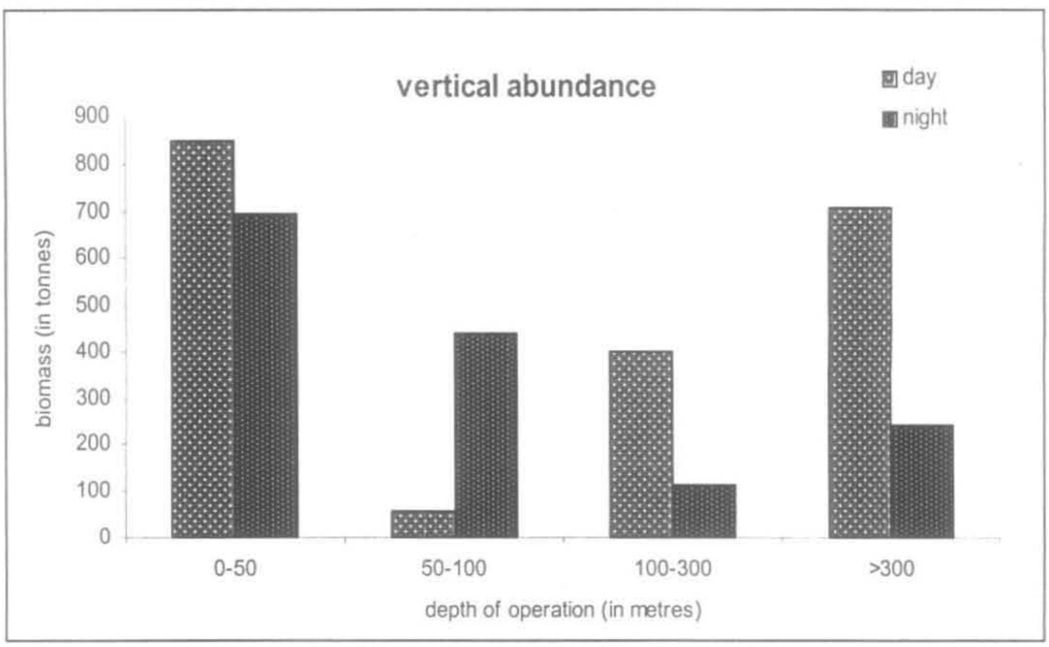


Fig.43. Vertical abundance of Leptocephali (day and night)

e) Diurnal variation

The biomass (average) leptocephali was maximum (1797.77t) during the early hours of the day between 00 00 – 04 00 hours where as the minimum was between 12 00 – 16 00 hours (205.15t). (Fig.45)

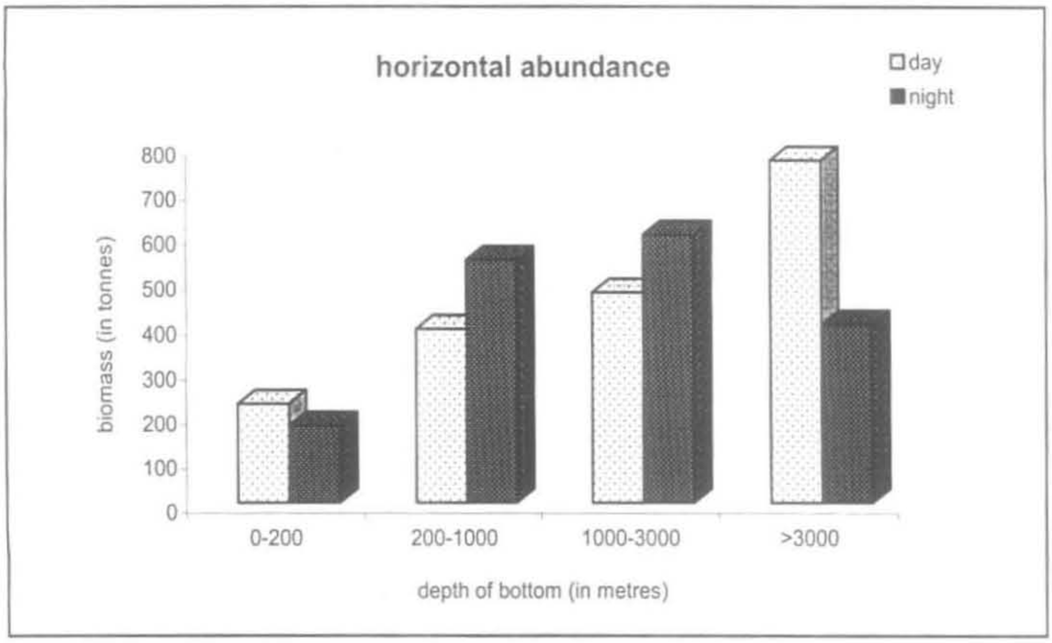


Fig.44. Horizontal abundance (day and night) of Leptocephali

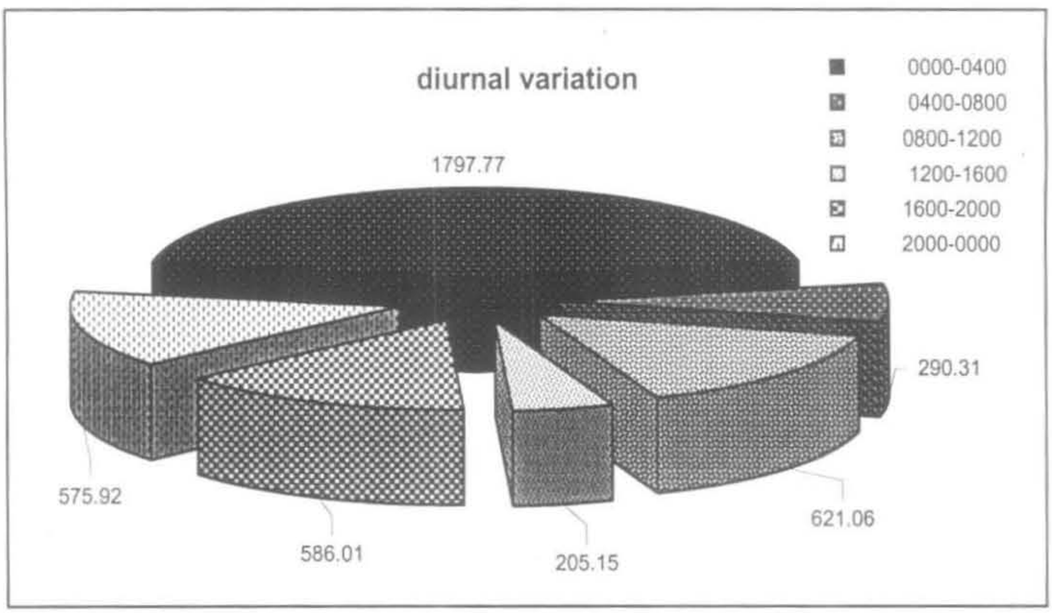


Fig.45. Diurnal variation in the Biomass of Leptocephali

Biomass estimation of major families

The leptocephalid biomass on the south west coast of India was constituted mainly by leptocephali belonging to five families viz. Congridae, Ophichthidae, Muraenidae, Nemichthyidae and Synaphobranchidae (Fig.46). Of the five families leptocephali of Congridae, Ophichthidae and Muraenidae dominated the catch. The representation by the other two families – Nemichthyidae (12 stations) and Synaphobranchidae (11 stations) were very poor in comparison, out of the 84 stations.

Family – Congridae

This was the largest represented family accounting to 30% of the total leptocephalid biomass of the south west coast of India. It had a fairly continuous abundance (in tones) along the south west coast (Fig.47). The abundance was maximum (>1000t) in the 9° latitude, off Cochin.

Geographical abundance

The congrid leptocephali were abundant (in tones) through out the latitudes (6°N – 14°N) with its maximum abundance along the 9° latitude (328.01t), followed by 10° latitude (142.61t) (Fig.48). The abundance along the other latitudes was comparatively less (<100t) with the lowest abundance in the 11° latitude (29.38t).

Day – night variations

a) Latitude wise abundance

Leptocephali of the family Congridae was present through out the latitudes invariably of day and night. In comparison the nighttime biomass (average) was more than day. The highest abundance during night was at the 9° latitude with 789.83t, where as in the other latitudes it was low in comparison (<200t). The daytime high was at 10° latitude (111.95t) (Fig.49)

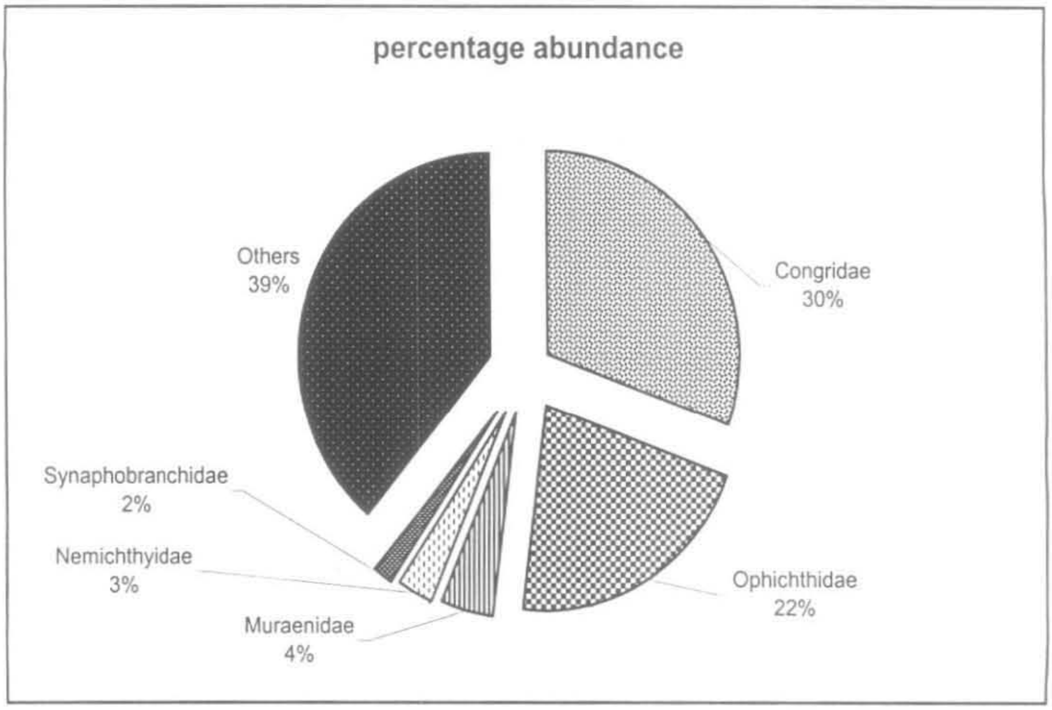


Fig.46. Percentage abundance of major families

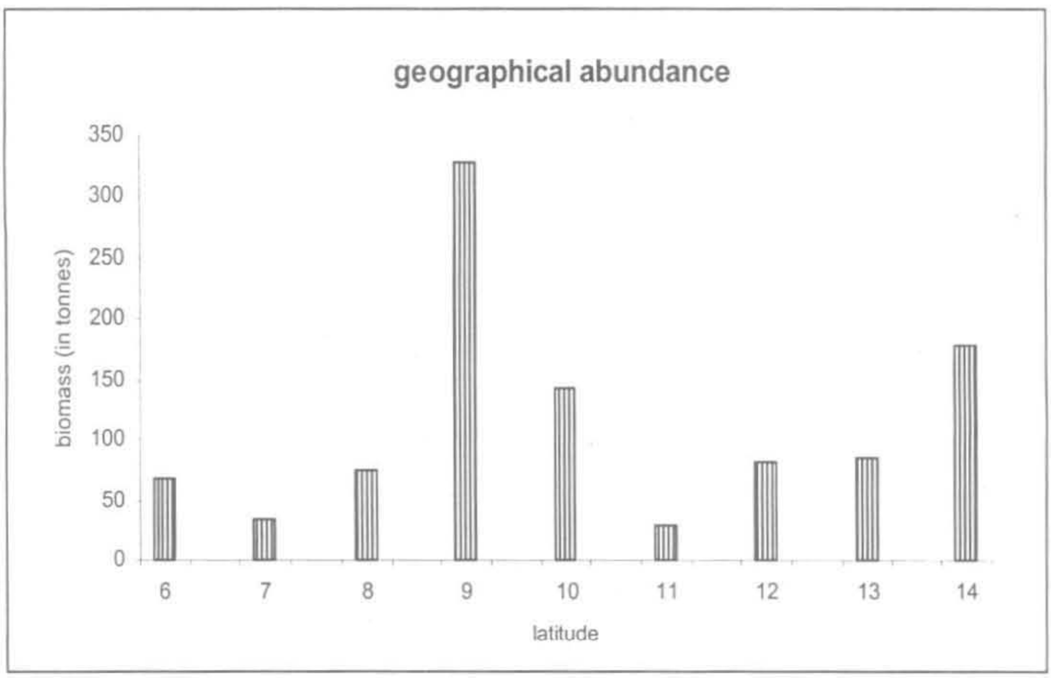


Fig.48. Congridae - Geographical abundance

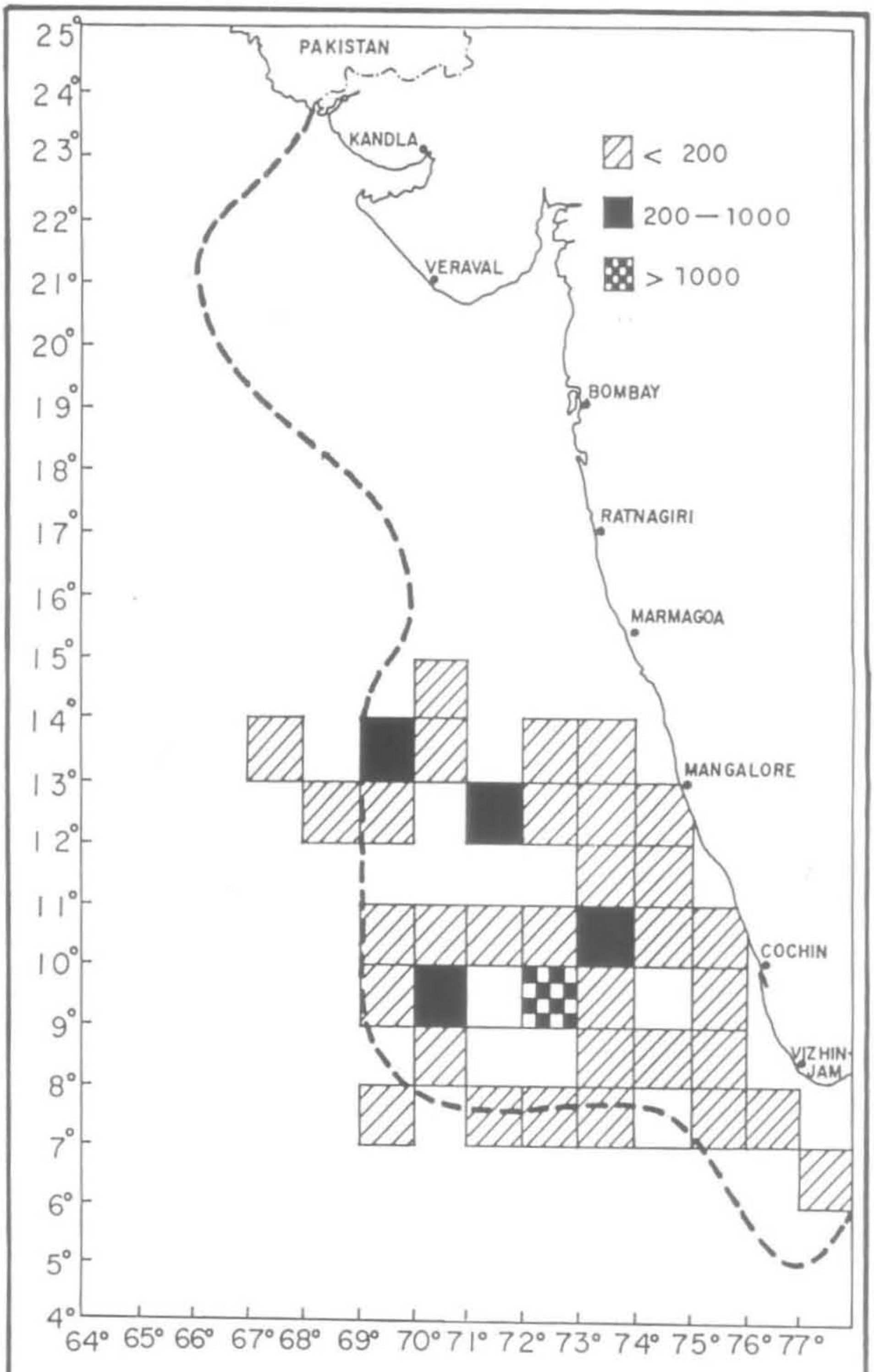


Fig. 47 Congridae – Total Biomass (Tonnes) in the South-West coast of India

b) Monthly variation

The monthly abundance of the congrid leptocephali shows that it was more on the month of September (186.92t) and low on October (7.22t). Diurnal variations were maximum in the month of May with 257.41t (night) and for the day it was the month of September (202.87t). (Fig.50)

c) Vertical abundance

The abundance of the family Congridae was more in the depth range of 0-50m (163.38t). Studies on the diurnal variation shows that the nighttime biomass (average) was more on the surface layers between 0-50m (191.79t), followed by 161.43t in the 50-100m depth range. Daytime biomass (average) was more in the depth range above 300m (Fig.51). In general, the nighttime biomass (average) was high in comparison.

d) Horizontal abundance

Bottom depth wise the congrid leptocephali were abundant more during night with a maximum of 189.73t in the 1000-3000m zone. The day biomass (average) was maximum above 3000m (91.23t). In general, the abundance was more in the 1000-3000m depth zone (266t). It was also noticed that the leptocephali was absent in the shallower region (0-200m). (Fig.52)

e) Temporal variation

The study revealed that the leptocephalid biomass (average) was maximum in the late hours of the day between 20 00-00 00 hours (193.25t), followed by 163.28t in the early hours of the day between 00 00-04 00hours (Fig 53). The least biomass (average) was recorded between 08 00-12 00 hours (32.66t).

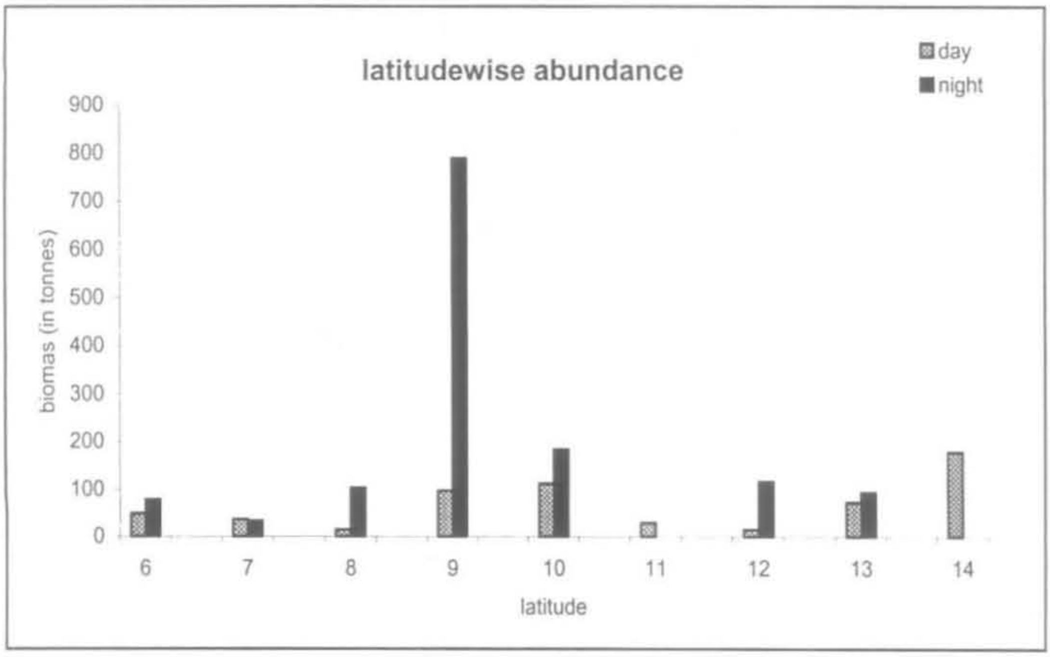


Fig.49. Congridae - Latitude wise abundance (day and night)

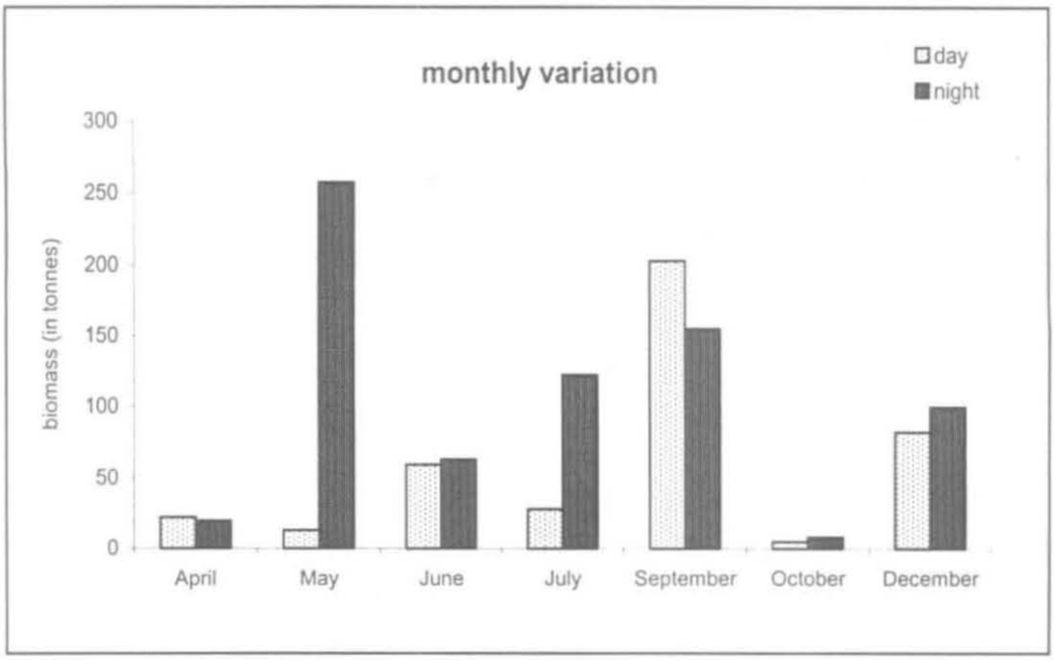


Fig.50. Congridae - Monthly variation (day and night)

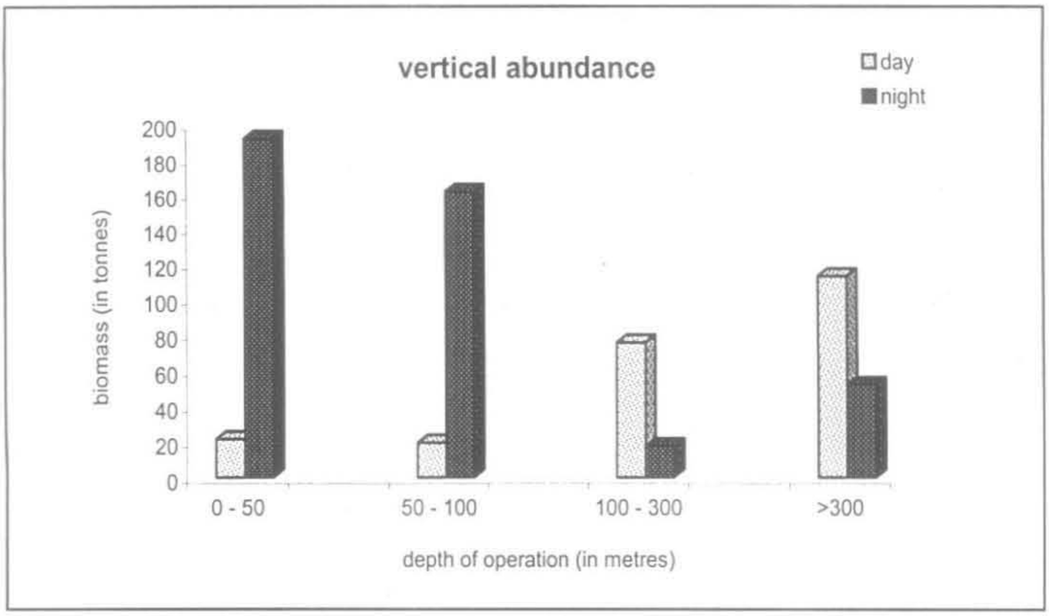


Fig.51. Congridae - Vertical abundance (day and night)

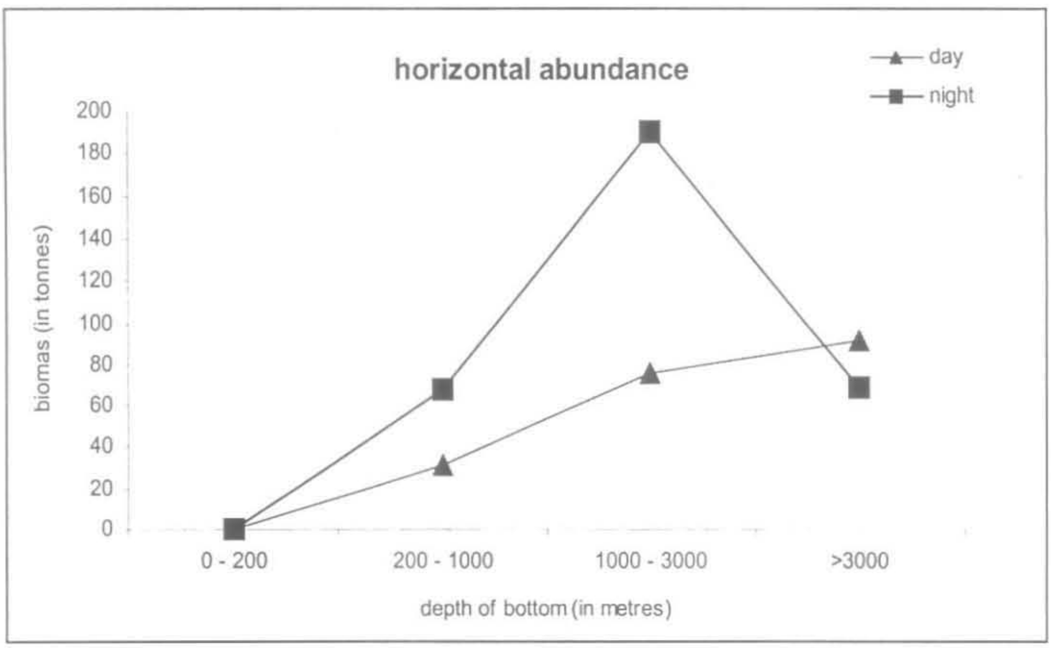


Fig.52. Congridae - Horizontal abundance (day and night)

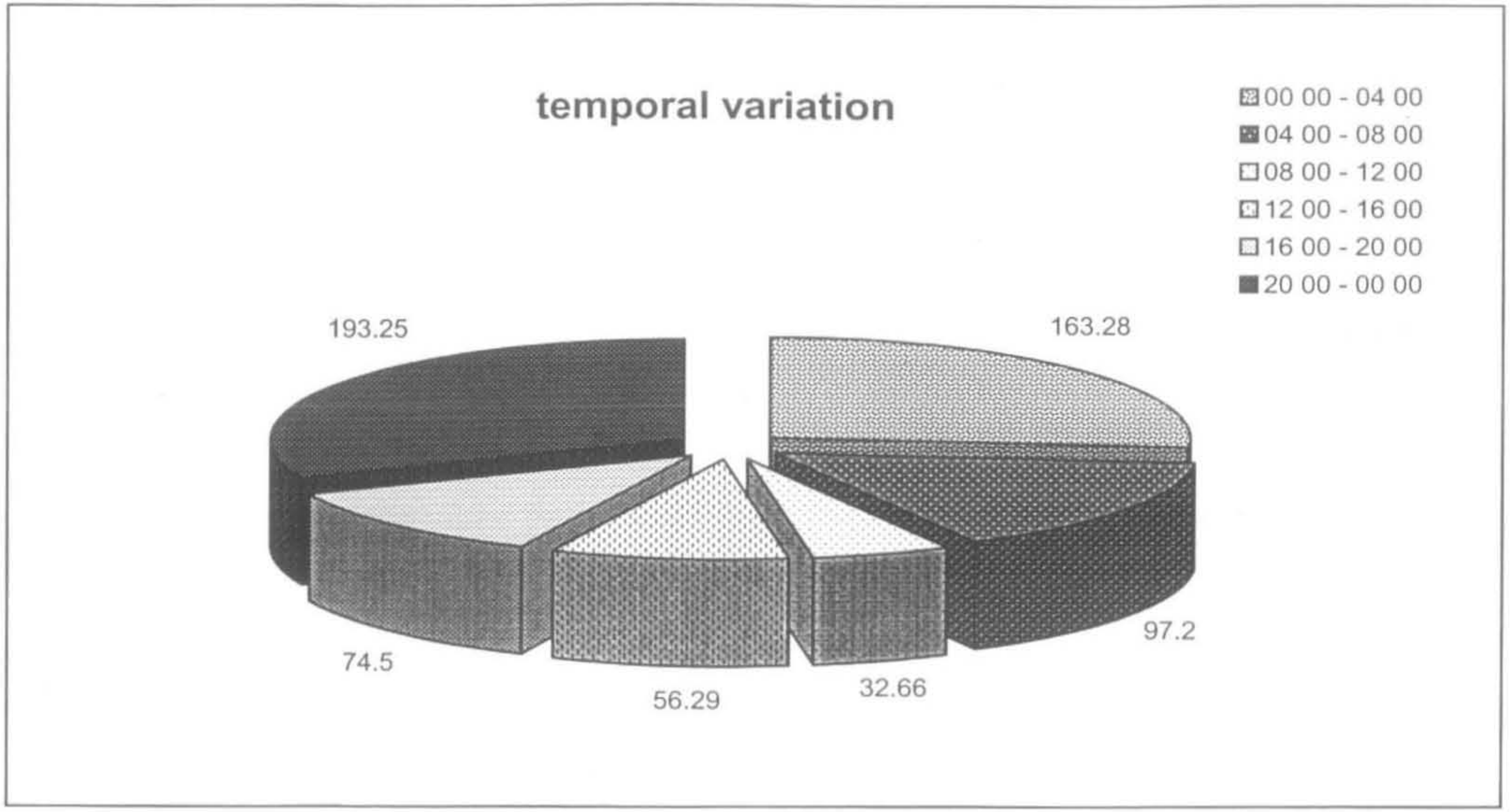


Fig.53. Congridae - Temporal variation (day and night)

Family – Ophichthidae

The second largest abundant family, Ophichthid leptocephali formed 22%of the biomass in the south west coast. Though abundant, the Ophichthid leptocephali do not had a continuous distribution like that of Congridae.

Geographical abundance

Geographical abundance (in tones) shows that the ophichthid leptocephali were denser in the area off Mangalore (12° latitude) with a single high density area (>1000t). Towards the south abundance was less (<200t) in comparison but more or less evenly distributed. (Fig.54)

Day- night abundance

a) Latitudinal variation

Latitude wise the leptocephalid biomass (average) of the family Ophichthidae was high in 12° latitude (338.94t). Day night variations show that the night biomass (average) was more in the 12° latitude (440.37t) and 38.97t in the 9° latitude during day. (Fig.55)

b) Monthly variation

Studies revealed that the monthly abundance was maximum in the month of July with 688.6t and a lowest of 9.9t in June. Day-night variations in biomass (average) were maximum in the month of July (1013.11t) during night and October (336.46t) for day. (Fig.56)

c) Vertical abundance

Diurnal variations in the vertical abundance (depth of operation) of ophichthid leptocephali were maximum in the 50-100m range for night (261.68t) and 80.82t for day in the depth range above 300m. In general, the biomass (average) was maximum in the 50-100m depth range (285.18t). (Fig.57)

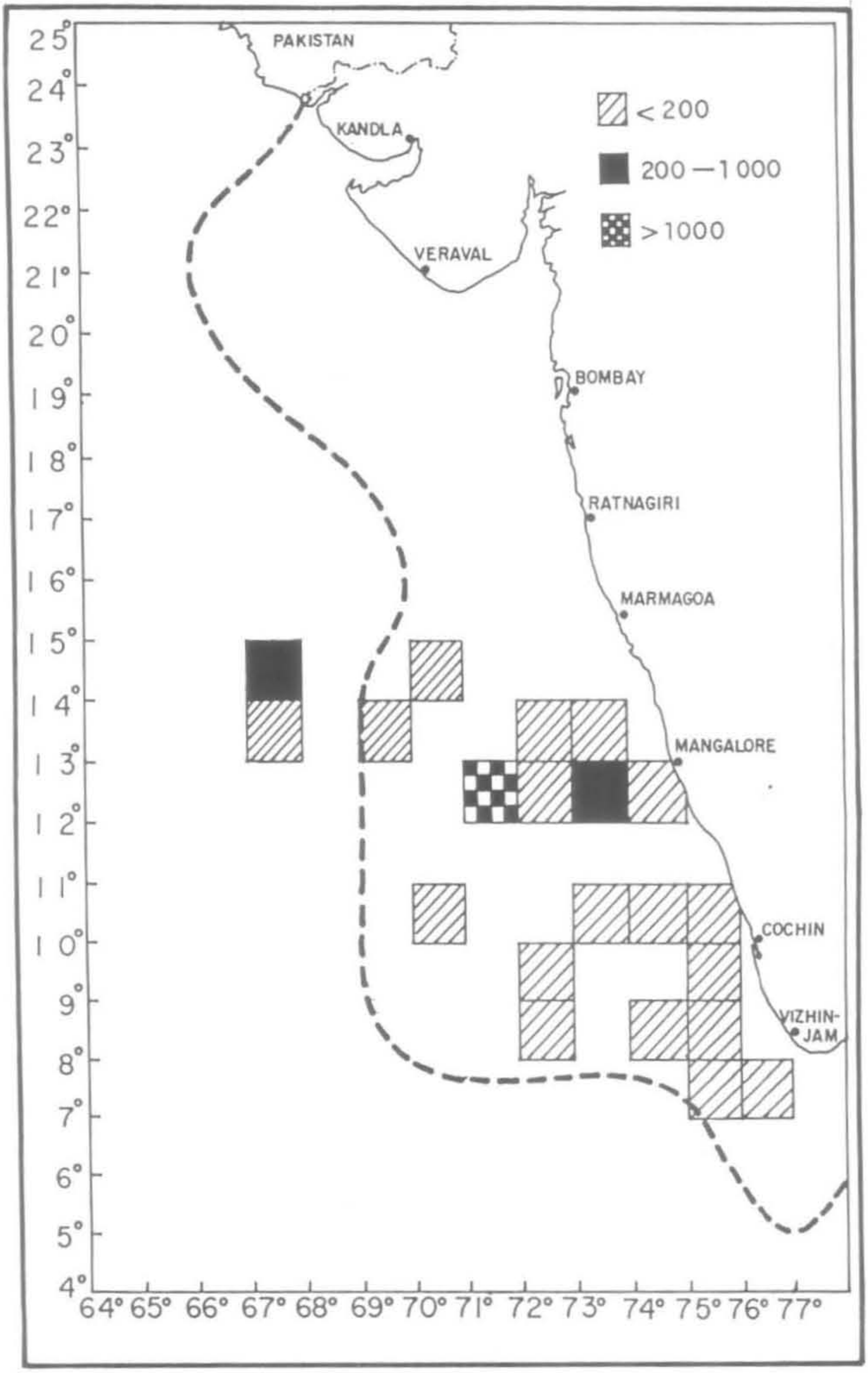


Fig. 54 Ophichthidae – Total Biomass (Tonnes) in the South-West coast of India

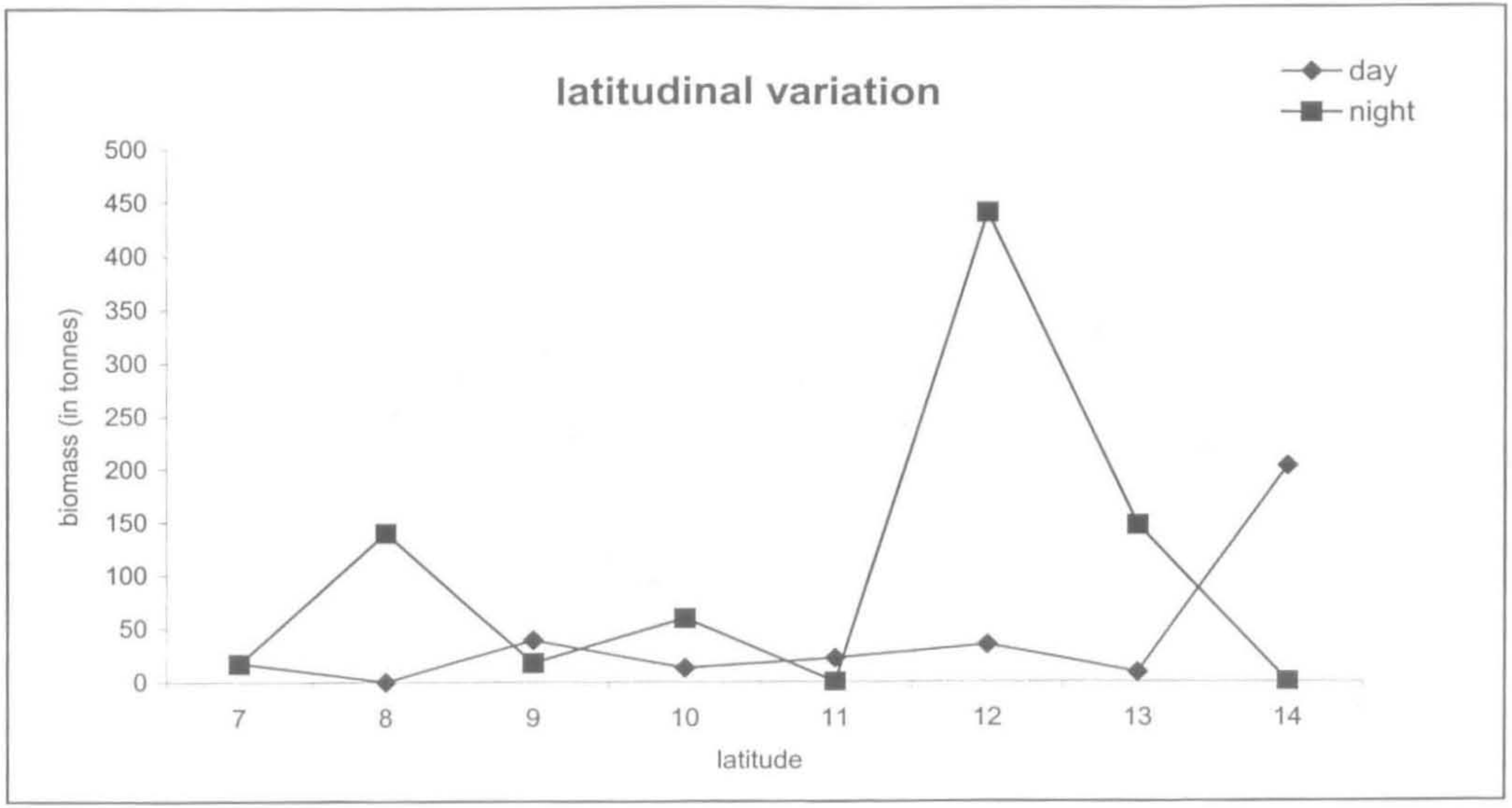


Fig.55.Ophichthidae - Latitudinal variation (day and night)

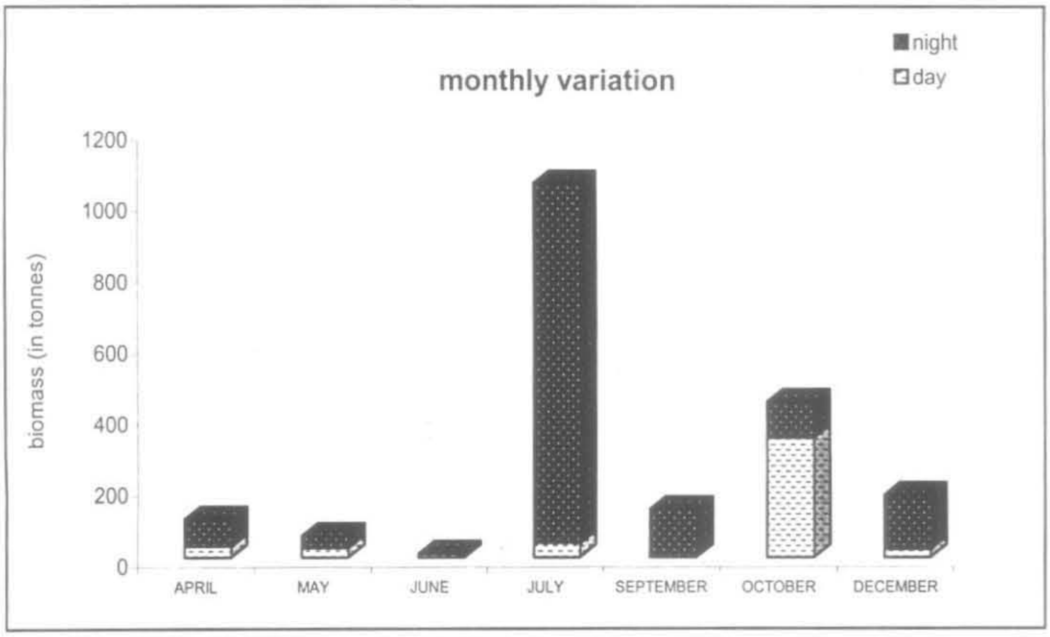


Fig.56. Ophichthidae - Monthly variation (day and night)

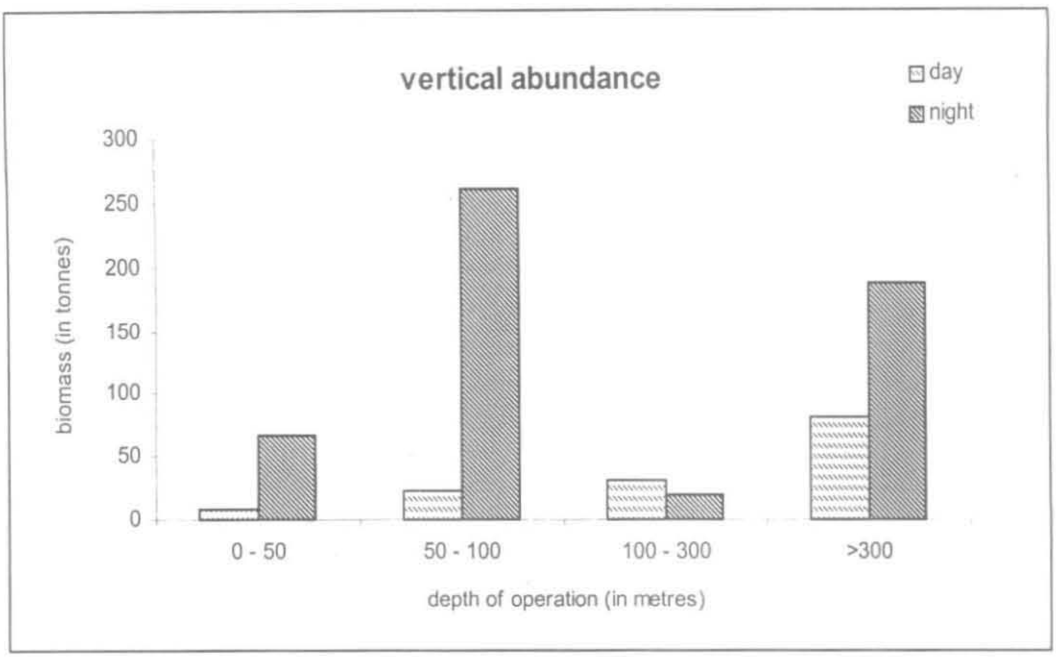


Fig.57 Ophichthidae - Vertical abundance (day and night)

d) Horizontal abundance

Analyses revealed that there is a gradual increase in the total biomass (average) with the increase in bottom depth up to the 1000-3000m mark (141.95t) after which it decreases (Fig.58). Diurnal variations show that the nighttime biomass (average) was more in the 1000-3000m depth zone (191.31t). The daytime average biomass was more in the zone above 3000m (202.87t) where as in the other depth zones it was comparatively very less (<30t) (Fig.59).

e) Diurnal variation

Diurnal abundance was more during the early hours of the day between 00 00-04 00 hours (534.38t), followed by 390.07t between 04 00-08 00 hours. Rest of the day the average biomass was well below 100t, with the lowest of 12.99t between 08 00-12 00 hours. (Fig.60)

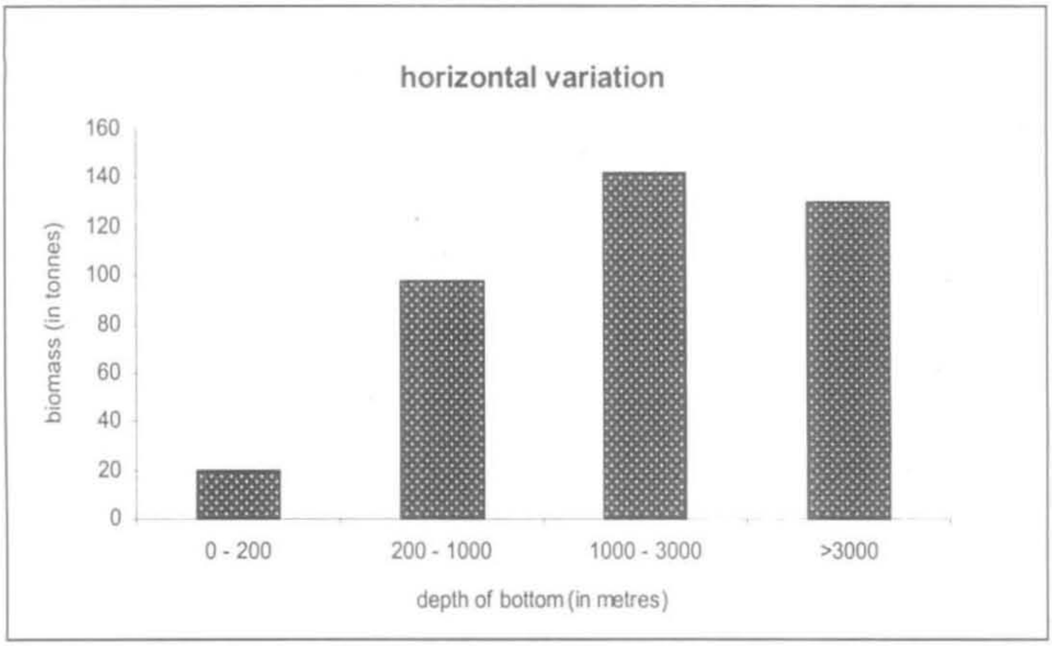


Fig.58. Ophichthidae - Horizontal variation

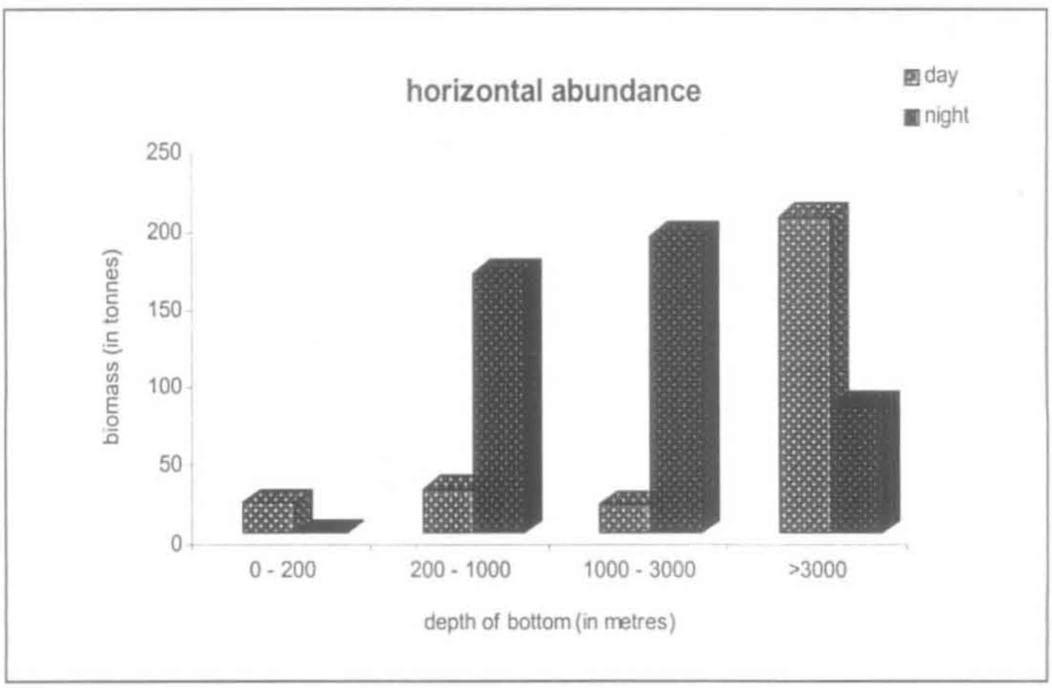


Fig.59. Ophichthidae - Horizontal abundance (day and night)

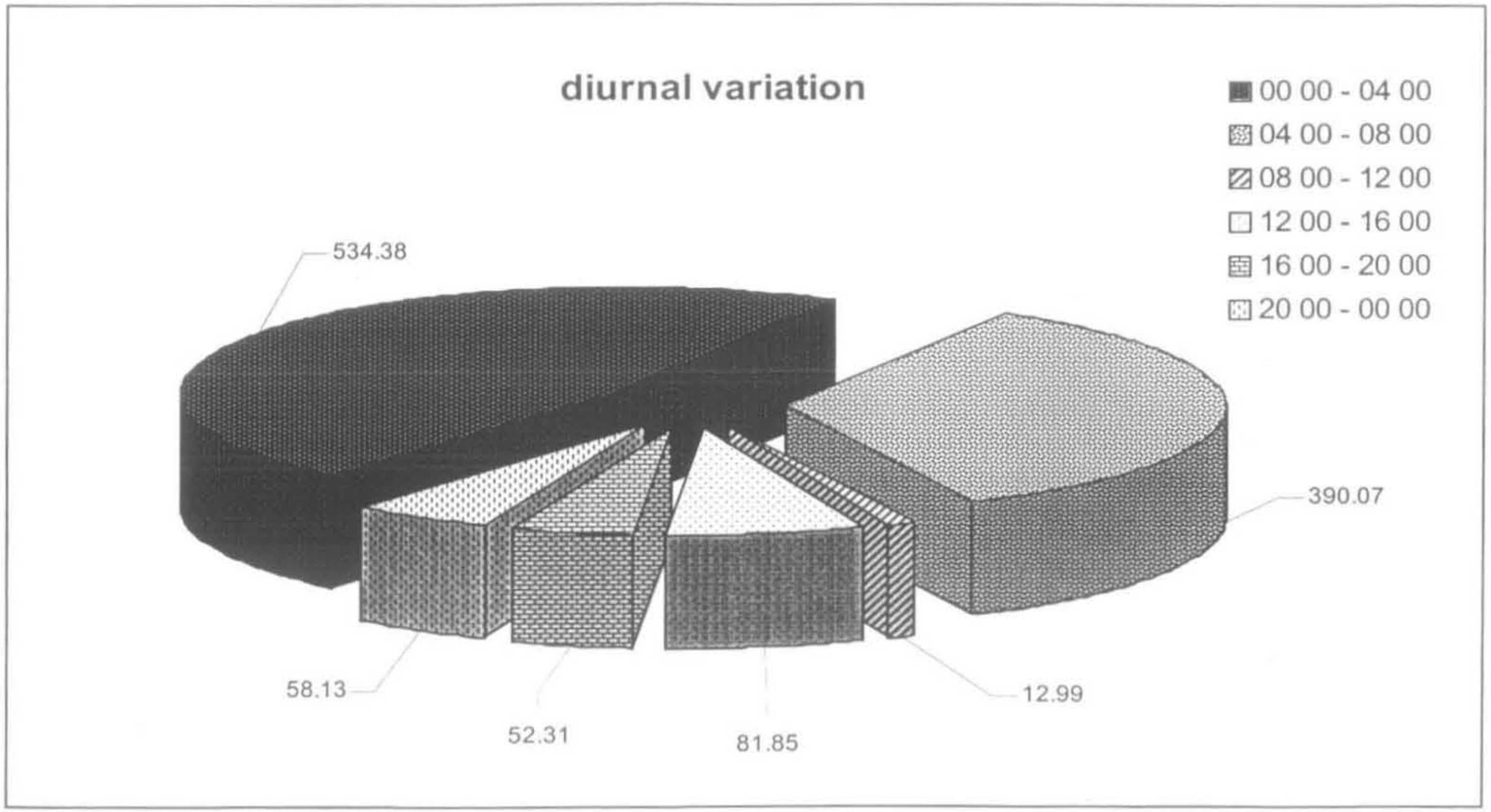


Fig.60. Ophichthidae - Diurnal variation

Family - Muraenidae

Though the third largest family in the leptocephali collection of the south west coast of India, the percentage concentration of the family Muraenidae was very less in comparison with the other two families viz. Congridae and Ophichthidae, forming only 4% of the total biomass. It was present on 27 stations out of the 84 stations sampled.

Geographical variations

The abundance (in tones) of muraenid leptocephali was more or less even towards the south with two high density areas- one on 9° latitude, off Cochin and the other off Mangalore on 12° latitude. (Fig.61)

Day-night variations

a) Latitudinal variation

The studies revealed that the nighttime average biomass (in tones) was high in 13° latitude (108.86t) where as the day in 9° latitude (46.39t) (Fig.62). In general, the average biomass was maximum in the 13° latitude (64.63t).

b) Vertical and horizontal variations

Analyses revealed that vertically (depth of operation) the muraenid average biomass (in tones) was more in the 50-100m depth range (41.39t) during night and in the 100-300m depth range during day (43.54t) (Fig.63). Horizontally (depth of bottom) the nighttime biomass (average) was high in the 200-1000m depth zone, where as that of day in the depth above 3000m (52.78t). The muraenid leptocephali were totally absent in the 0-200m depth zone (Fig.64).

c) Monthly abundance

The monthly variations in average biomass plotted almost similar higher values in two months- September (60.62t) and December (60.38t). Day-night variations in average biomass shows that the nighttime biomass was high in the month of December (80.16t) and that of day in September (66.80t). (Fig.65)

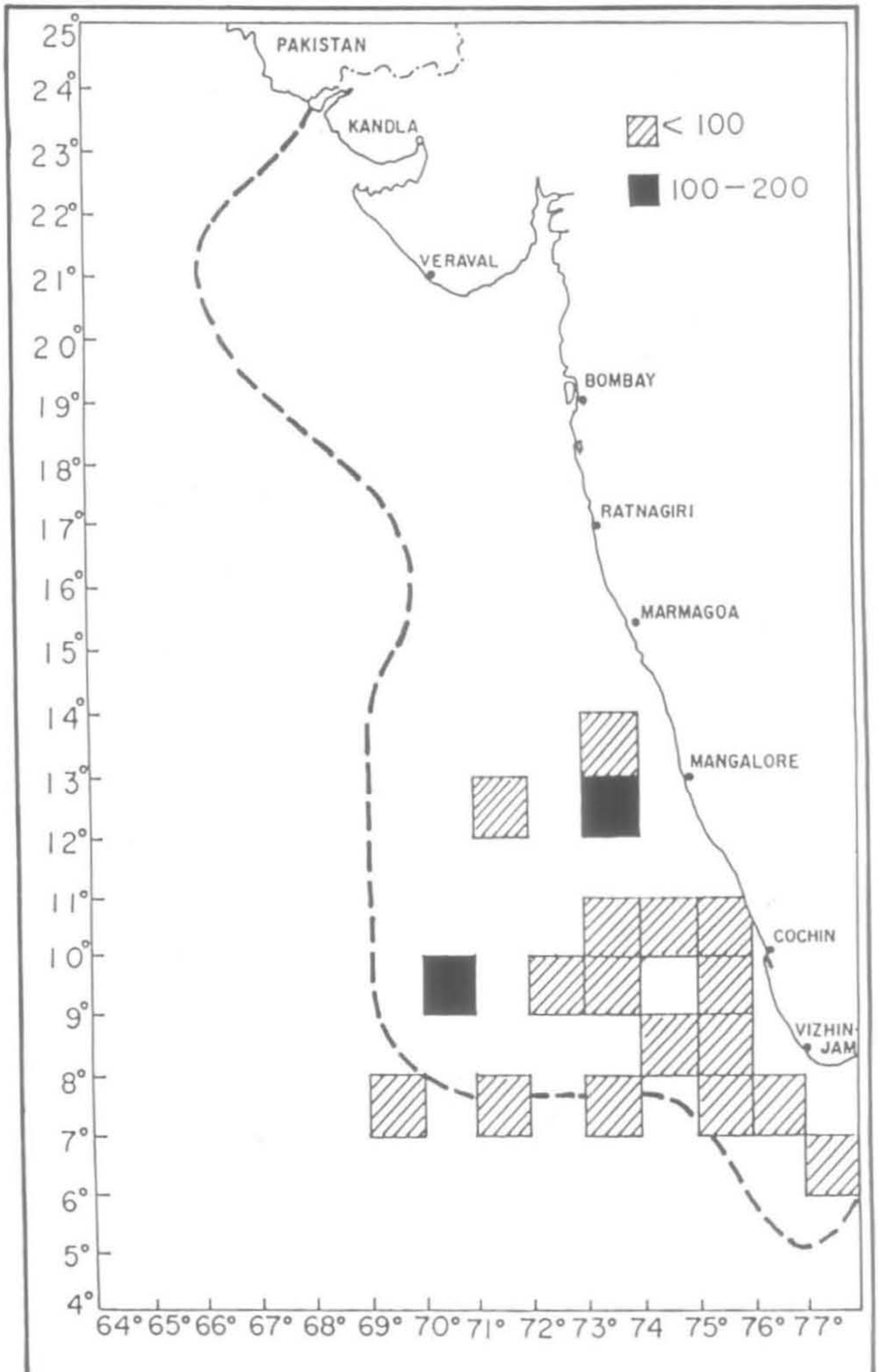


Fig : 61 Muraenidae Total Biomass (Tonnes) in the South West Coast of India

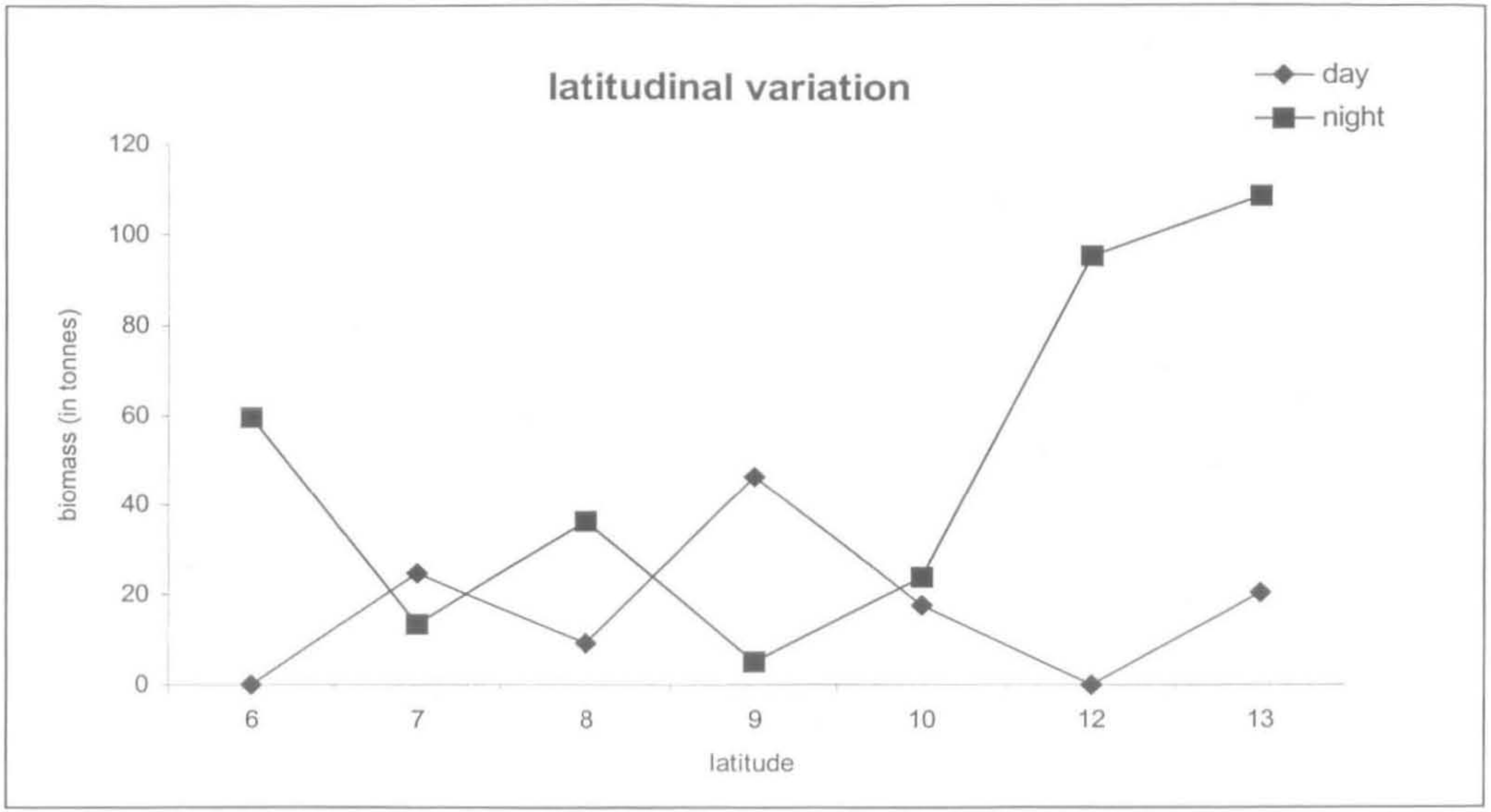


Fig.62. Muraenidae - Latitudinal variation (day and night)

d) Diurnal variation

The estimated average biomass plotted a higher value of 185.55t between 00 00-04 00 hours of the day. The biomass recorded a low value between 08 00-12 00 hours (18.56t). (Fig.66)

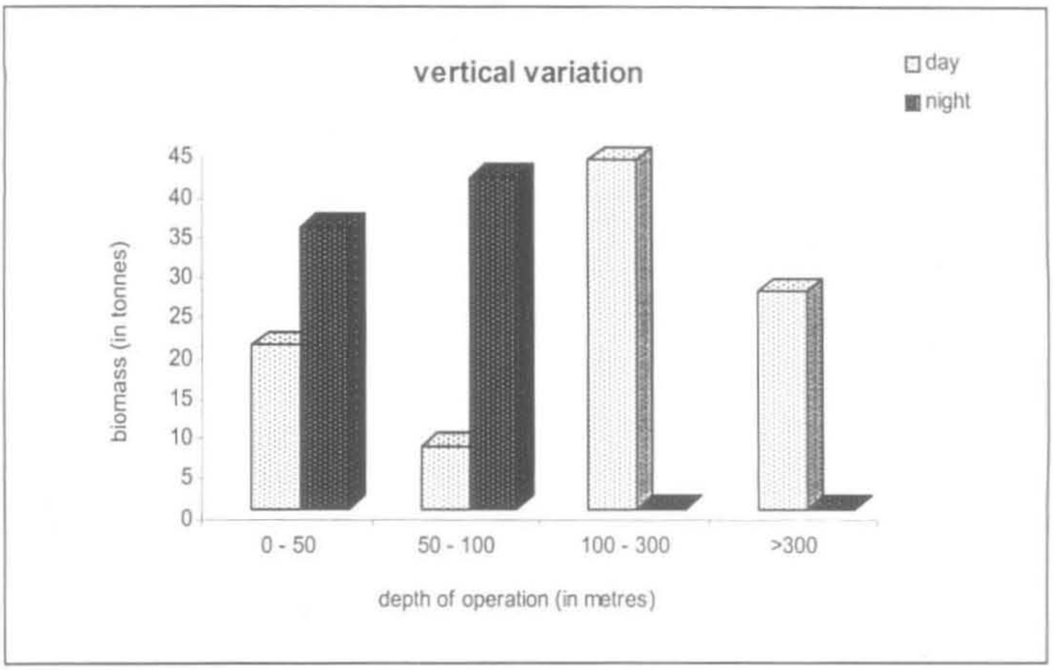


Fig.63. Muraenidae - Vertical variation (day and night)

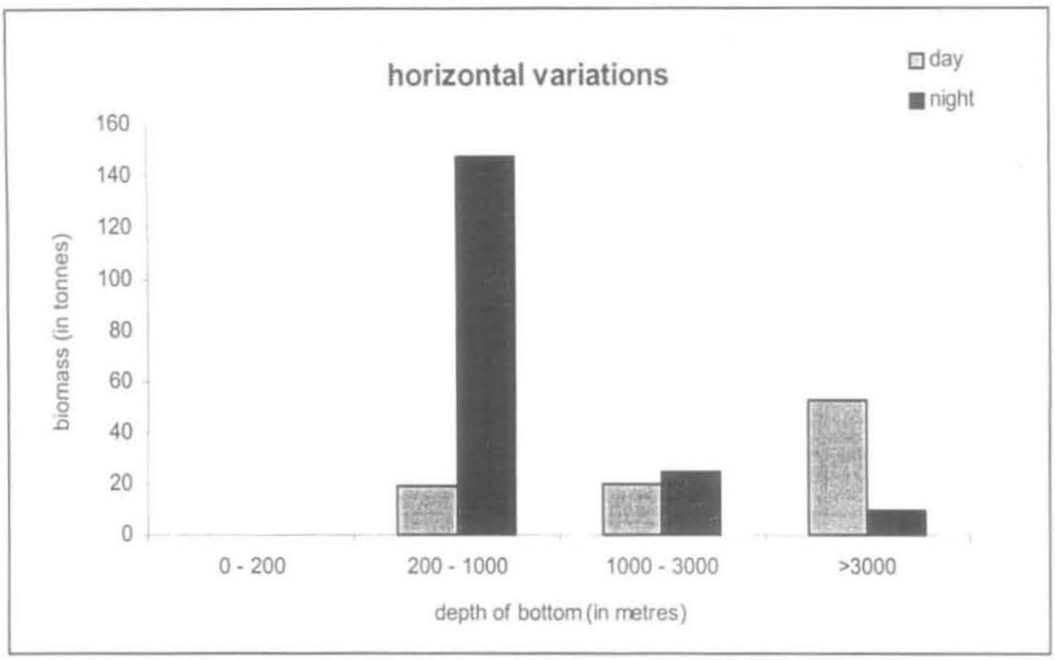


Fig.64. Muraenidae - Horizontal variation (day and night)

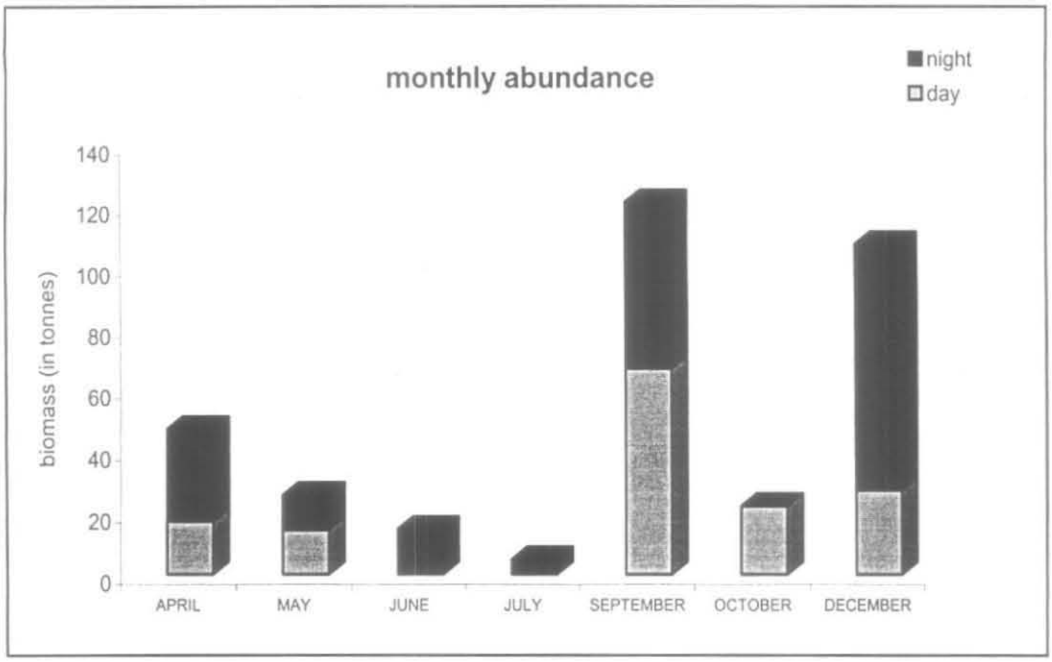


Fig.65. Muraenidae - Monthly abundance (day and night)

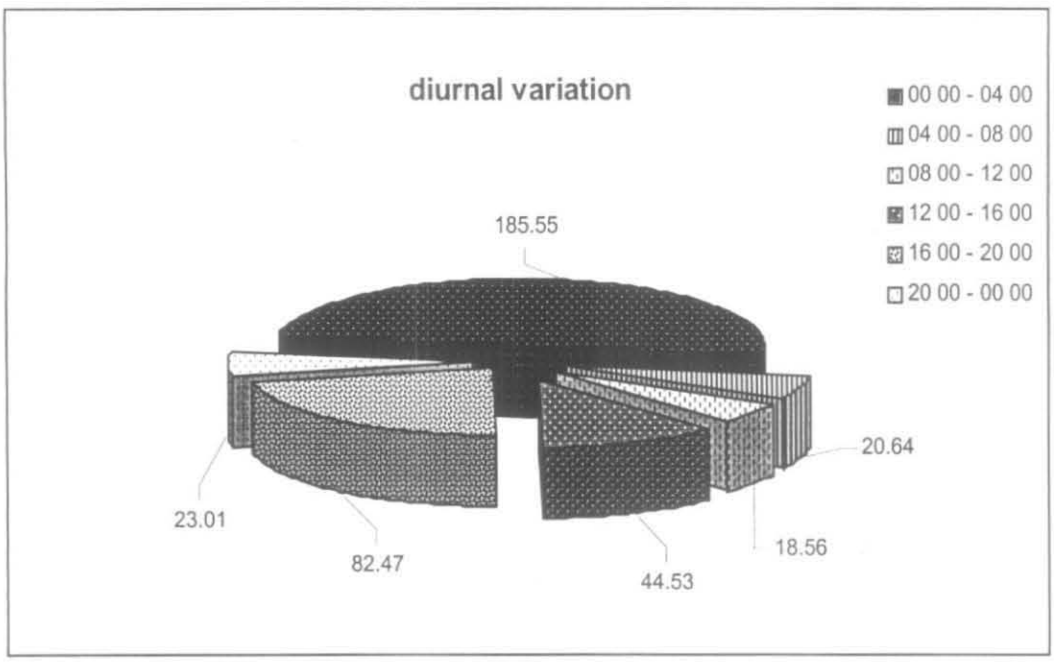


Fig.66. Muraenidae - Diurnal variation (day and night)

Discussion

Discussion

The Deep Scattering Layer (DSL) is very rich in the quantitative abundance of micro and macro nekton. Leptocephali formed one of the major groups in the total nektonic biomass of the samples collected from the Arabian Sea. It constituted to about 7.5% of the total fish biomass in the DSL of the EEZ of India (Menon, 1990). The leptocephali were represented mainly by 8 genera viz. *Uroconger, Ariosoma, Ophisurus, Ophichthus, Phaenomonas, Gymnothorax, Uropterygius, Anarchias*, 2 species (*Uroconger lepturus* and *Congrellus anago*) and some unidentified types belonging to five families viz. Congridae, Ophichthidae, Muraenidae, Nemichthyidae, and Synaphobranchidae.

The historic studies made by Johannes Schmidt (1922a) on larvae of the North Atlantic species of *Anguilla* and later by Jespersen (1942) on Indo-Pacific Anguilla larvae are the most informative works available on the early life histories of eels.Very few works have been carried out on leptocephali in general, especially on systematics of leptocephali from the Indian Seas. Some of the earlier workers who described the leptocephali include Risso (1810), Cocco (1829), Lesson (1830), Costa (1844, 1856), Kolliker (1853), Kaup (1856 b), Peters (1859, 1864), Day (1865a,) Southwell and Prashad (1919), Delsman (1933), Deraniyagala (1934), Bertin (1935a), Beebe (1935b), Beebe and Crane (1936, 1937 a,b), Ege (1939), Jesperson (1942), Aiyar *et al.* (1944), Gopinath (1946, 1950), Nair (1946,1948), Nair and Bhimachar (1950), Bapat (1955), Jones and Pantulu (1955)etc. In the 1960's the tempo of work on the leptocephali began to accelerate, corresponding to an increased attention to the systematic relationship of eels with many workers like Nair and Bhimachar (1960), Nair and Dharmamba (1960), Nair and Mohamed (1960 a,b,c,d,e), Ganapati and Raju (1960, 1963), Orton (1963, 1964a,b), Castle (1964a, 1965a,b,c,d, 1969c) etc. contributing to it. A preliminary systematics of leptocephali from the Indian waters was done by Gopinath (1946,1950) from the Trivandrum coast. He described the leptocephali of *Muraenesox cinereus*, *Congrellus anago* and a few unidentified leptocephali. Larvae of *Congrellus anago* (Congridae) were present in considerable numbers in the present collection. The characteristic feature

of this larva appears to be the presence of stellate chromatophores on the base of anal and caudal fin rays as described by Nair (1948). The later authors (Castle 1964a, Mochioka *et al.*, 1991) described the same as *Ariosoma scheelei* considering it as a synonym of *C. anago*. The study specimen also coincides well with the characters described by the above authors. In spite of these some other workers also described a few leptocephali like *Leptocephalus milnei* (Southwell and Prshad, 1919), Larva I of Deraniyagala (1934) etc., which a resemblance with *C. anago* but their identity cannot be determined as they were poorly described. The myomere numbers in the above specimens varied between 108-120, where as in the study specimen it was 118.

Another dominant leptocephali in the sample analysed was of *Uroconger lepturus* (Congridae). The distinguishing character of this larva is the presence of group of black, branched chromatophores below the eye. Other characters include the presence of a single series of midlateral melanophores and ventral pigment extending the length of the body. This larva was earlier described by Nair (1946,1948), Nair and Mohamed (1960c) and Socolovski (1975). Smith (1979) described the above larval characters as common to three genera of Congridae viz. *Uroconger*, *Rhechias* and *Pseudoxenomystax*. Among this the genus Uroconger can be distinguished by their high myomere count (more than 200). The study specimen very well confirms with the distinguishing characters described above and also has more than 200 myomeres.

Ariosoma type – Exterillium larvae with an outer intestine was earlier described by Mochioka *et al.*(1982) and James and Prabhadevi (1990). There are a few unidentified leptocephali whose identity cannot be ascertained with certainty.

The leptocephali of the family Ophichthidae can be identified by the thickenings or humps or loops (three or more) on the intestine, which is a characteristic feature. In the present study it was identified to the genus level viz. *Ophicthus*, *Ophisurus* and *Phaenomonas*. The eggs and larvae of the family Ophichthidae was described by authors like Delsman (1933), Jones and Pantulu (1955), Ganapati and Raju (1960), Nair and Dharmamba (1960), Nair and Mohamed

(1960d), Castle (1965c), Fahay and Obenchain (1978), Smith (1979), Rani Mary George (1987) and others. Few unidentified leptocephali were also present in the collection.

The muraenid leptocephali have been described by many authors like Nair (1947, 1948), Pantulu and Jones (1954), Castle (1965b), Bensam (1966), Smith (1979, 1989h) etc. The larva can be identified by the presence of a greatly reduced pectoral fin, a moderate to deep body and with a characteristic round caudal fin with the dorsal and anal fin restricted to it. Three genera of muraenid larvae have been identified in the present study viz. *Gymnothorax*, *Uropterygius*, and *Anarchias*. The systematics of the leptocephali of the two families viz. Nemichthyidae and Synaphobranchidae have so far not been carried out from Indian waters except for some studies by Castle (1965 a), Smith (1979) etc. A few unidentified leptocephali constituted the two families in the present study. Considerable advances are possible in the systematics and general biology of eels once their larvae have been identified.

In the present work an attempt is made to study the metamorphosing stages of *Congrellus anago* from the Indian waters. Metamorphosing stages of the leptocephali was described by various authors. Some of the earlier workers include Delage (1886), who confirmed Gill's (1864) hypothesis by raising a specimen in an aquarium where as the first account of eel eggs was given by Raffaele (1888) who studied the early development of five types of unidentified eggs from the Bay of Naples. In India, the earlier studies on the different stages of metamorphosis of eel larvae were carried out by Nair (1947) on the leptocephali of *Muraenesox cinereus* and *Muraena macrura* and later on by Jones and Pantulu (1952), Pantutlu and Jones (1954), Nair and Dharmamba (1960), Nair and Mohamed (1960 a,b,c) and Ganapati and Raju (1960).Castle (1970b) studied the metamorphosis of the eel *Derichthys serpentines* (Derichthyidae) from the South Atlantic.

The leptocephali were found to have a wide distribution along the west coast of India from the coastal waters to the deep sea. The study revealed that the occurrence of leptocephali was maximum during monsoon period. The highest abundance of 18.32 no/1000m^3/haul was recorded at the 12°30 latitude and 71° 29 longitude. Comparatively the night abundance was high (154.95 no/1000m^3) than the day (57.32 no/1000m^3). Miller *et al.* (2002) in their study on the leptocephali of Kuroshio Current region and east China Sea found that there is no significant difference between oblique or step tows or tows made during day time, at night, around sun set, or around sunrise. This is in contrast to collections with an IKMT in the clear, lower productivity water of the open ocean, where catches of leptocephali during the day have been found to be significantly lower than those at night (Miller and Mc Cleave, 1994).

Earlier studies on the distribution of anguillid leptocephali (Kleckner and Mc Cleave, 1985) have revealed that the high concentration follows the areas of upwelling and circulatory currents in the Ocean. Nair (1947) stated that there is no seasonality in the occurrence of leptocephali and the eels in the tropics breed through out the year. Seasonal variation in the abundance of ichthyoplankton in the Arabian Sea (Peter, 1973) was observed maximum during southwest monsoon in areas of upwelling and places under the influence of divergence. Miller *et al.* (2002) studied the distribution of leptocephali in the Kuroshio Current and East China Sea and stated that the most abundant leptocephali in the region were of the eel families Congridae, Synaphobranchidae, Ophichthidae, Muraenidae and Nettastomatidae. Distribution of leptocephali from the Indian seas were carried out by James and Prabhadevi (1990), where they studied the distribution in the Deep Scattering Layer of the Indian EEZ and observed that the occurrence and distribution of leptocephali indicated that maximum number of larvae and positive stations were located in the Arabian Sea where high salinity water mass (Sen Gupta *et al.*, 1976) existed. They concluded that the distribution of leptocephali in Bay of Bengal and the equatorial water were less when compared to Arabian Sea and also stated that the occurrence of leptocephali showed maximum during post monsoon and pre monsoon periods even though regular seasonality was not observed in seas around India.

Physical and behavioural controls on the oceanic distribution and migration of leptocephali in the Subtropical Convergence Zone within the Sargasso Sea

(Mc Cleave, 1993) where the spawning and distribution of leptocephali of five families of eels were studied. He concluded that the distribution across fronts of leptocephali of the catadromous species of *Anguilla*, shelf dwelling species and oceanic species are different in winter. Wippelhauser *et al.* (1996) studying the spawning and larval distribution of Snipe eels (Family Nemichthyidae) in the Sargasso Sea stated that small *Nemichthys scolopaceus* leptocephali (6-15mm) were abundant in February-April and smaller leptocephali were consistently more abundant, but larger leptocephali were more widely distributed. The study by Castonguay and Mc Cleave (1987) determined the distributions and abundances of two of the most abundant leptocephali, *Derichthys serpentines* and *Nessorhamphus ingolfianus* (Derichthyidae) in the western Sargasso Sea in summer and fall, related the distributions to oceanic features and contrasted the distributions with those of *Anguilla rostrata* and *A. anguilla* (Angullidae) with respect to retention in the oceanic realm. Castle (1970b) stated the distribution of *Derichthys serpentinus* (Derichthyidae) in the Indo-West Pacific also, as well as in the Atlantic and east Pacific.

The dynamic circulation around the Bahama Banks, when and where shelf eels spawn in relation to these banks may have a significant effect on how their leptocephali are distributed in the Sargasso Sea and Florida Current region (Miller, 1995). The spawning locations in the Sargasso Sea and the general distribution of the leptocephali of the American and European eels (Schmidt, 1922a; Schoth and Tesch, 1982; Kleckner *et al.*, 1983; Boetius and Harding, 1985; Kleckner and Mc Cleave, 1985,1988; Wippelhauser *et al.*, 1985; Castonguay and Mc Cleave, 1987; Mc Cleave and Kleckner, 1987; Tesch and Wegner, 1990) are relatively well known.

The family Congridae constituted as the most abundant family with a percentage abundance of 44% of the total in the south west coast of India. Maximum concentration was found in the 10° and 9° latitude, together accounting to about 79.18% in the south west coast. Month of May recorded the highest percentage abundance of 80.04. Night catch was high with an average of 1.03 no/1000m^3. General catch trend also shows that nighttime represented maximum share (82.19%).

Ophichthidae formed as the second largest (30%) family in the collection. It shows a maximum aggregation (78.08%) in the 12° latitude (off Mangalore). Monthly abundance was maximum during the month of July (73.66%). Night catch constituted high with a total of 21.21 no/1000m^3 and day a low of 1.63 no/1000m^3. The concentration was high in the depth of 50-100m (depth of operation) with a percentage abundance of 86.59. There was an increase in the percentage abundance of leptocephali in relation to the increase in the depth of bottom, with a maximum recorded at the 1000-3000m depth zone (85.49%) after which it decreases.

Another dominant family though in less number was Muraenidae with a presence of only 2.65% of the total. The leptocephali had an evenly distribution with no dense pocket of abundance. The percentage abundance was maximum (61.11) in the depth of 50-100m (depth of operation). There was a total absence of muraenid leptocephali in the 0-200m (depth of bottom) depth zone with a maximum in the 1000-3000m (50%).

Family wise distribution of leptocephali has so far not been reported from Indian Seas. Some studies have been reported from the world Oceans (Castle, 1969b; Wippelhauser *et al.*, 1985,1996; Castonguay and Mc Cleave, 1987; Kleckner and Mc Cleave, 1985, 1988; Mc Cleave, 1993; Mc Cleave and Miller, 1994; Miller and Mc Cleave, 1994; Miller, 1995; Miller *et al.*, 2002;). Without having adequate data of the pelagic trawl catch and relating it to the major oceanographic parameters, it is impossible to locate the breeding grounds of eels in the Indian Seas.

Biomass of leptocephali has not been worked out except for a few scattered works. Castle (1969) working on the samples from the eastern Indian Ocean (110°E) stated that the biomass was greatest during early winter at 26°S, but other maxima occur in early winter from 9°S to 17°S and at 23°S during mid summer. In India, no such studies have been carried out so far and the present one being the first study in these lines. In the present study the biomass of Congridae, Ophichthidae, and Muraenidae were estimated. The family Congridae accounting 30% of the total leptocephalid biomass followed by Ophichthidae (22%) and Muraenidae (4%). Nemichthyidae and Synaphobranchidae formed only a negligible percent of the total biomass. The spatial and temporal variation of the biomass of the leptocephali was estimated in the present study for the first time along the south west coast of India. The present study revealed that the biomass of leptocephali was maximum in the north west coast with maximum of 6481.88t in the area 19° N-68 E°. Overall the night biomass was maximum with an average of 1797.77t during the early hours of the day (00 00 – 04 00hrs). Similar estimates were also been carried out on the biomass of Pelagic shrimps (Karuppasamy, 2001) and Photicthyidae (Vimala, 2002) from the Deep Scattering Layer of the west coast of India.

Summary

Summary

The present investigation was carried out on the leptocephali of the Deep Scattering Layer (DSL) of the south west coast of India. The aim of the study was to understand the distribution and abundance and also the major groups of leptocephali in space and time in the DSL. Samples for the study was collected between May 1998 to June 2001 onboard FORV Sagar Sampada. The salient features of the study are summarized as given below:

1. Samplings were carried out on 148 stations (81 night and 67 day) using IKMT on the west coast of India (6°-21° N latitude).
2. Specific area for study was the south west coast of India (6° to area below 15° N latitude)
3. In the west coast, the highest area of abundance (18.32 no/1000m^3) recorded from the area 12°30 N - 71°29 E.
4. Highest abundance (in tones) of leptocephali in the west coast recorded from area 19° N – 68° E (6481.88t)
5. Five major families viz. Congridae, Ophichthidae, Muraenidae, Nemichthyidae and Synaphobranchidae including 8genera, 2 species and a few other unidentified species.
6. Total biomass (no/1000m^3) of south west coast accounted to 35.85% of the west coast leptocephalid biomass.
7. Night catch of leptocephali formed 87% of the total catch in the south west coast and day 13%.
8. Congridae has the highest contribution (44%) closely followed by Ophichthidae (30%).
9. Maximum concentration of congrid leptocephali recorded between 9° and 10° N latitudes.
10. Diurnal variations show the maximum abundance of congrid leptocephali during late night hours (20 00 – 00 00 hours).
11. Vertical abundance of congrid leptocephali was maximum in the 50-100m range where as the horizontal abundance in 1000-3000m depth range.

12. The congrid leptocephali concentrated more, especially in the night, with in the 100m range.
13. Congrid leptocephali present to a maximum depth (depth of operation) of 420m.
14. Ophichthid leptocephali show maximum aggregation in the 12°N latitude.
15. Vertical abundance (depth of operation) of ophichthid leptocephali maximum at 50-100m depth and the abundance with respect to the depth of bottom was maximum in the zone of 1000-3000m.
16. Diurnal variation of ophichthid leptocephali was maximum during the early hours of the day between 04 00 – 08 00 hours.
17. Ophichthid leptocephali present to a maximum depth of 750m.
18. Muraenid leptocephali showed a slightly high abundance in 10°N latitude.
19. Vertically (depth of operation) the muraenid leptocephali were maximum in the 50-100m range where as horizontally (depth of bottom) it was at the 1000-3000m depth range.
20. Muraenid leptocephali were totally absent in 0-200m (depth of bottom) depth zone.
21. Diurnal abundance was maximum during the early hours of the day between 04 00 – 08 00 hours.
22. Muraenid leptocephali were present to a depth of 420m.
23. Nemichthyidae and Synaphobranchidae were abundant to a maximum depth of 380m and 400m, respectively.
24. Total leptocephalid biomass on the west coast was 76227.87 tones with a maximum recording at 19°N latitude, off Bombay (6481.88t).
25. Leptocephalid biomass (in tones) abundance was more prominent in the north west coast.
26. Nighttime leptocephalid biomass was more in comparison, on the north west coast of India.
27. Congrid biomass was maximum in 9°N latitude in the south west coast of India.

28. Vertical abundance of Congridae maximum in the 0-50m depth range (163.38t) and that of horizontal abundance in the 1000-3000m depth zone (266t).
29. Family Ophichthidae was abundant in the area off Mangalore (12°N latitude).
30. Vertical abundance of biomass (average) of Ophichthidae was maximum in the 50-100m depth range (285.18t).
31. An increase in the biomass (average) of Ophichthidae with an increase in the bottom depth was observed, with a maximum in the 1000-3000m mark (141.95t).
32. The muraenid biomass (average) was maximum in the 12°N latitude (64.63t).
33. Diurnal variations in the average biomass was higher (185.55t) between 00 00 – 04 00hours.

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